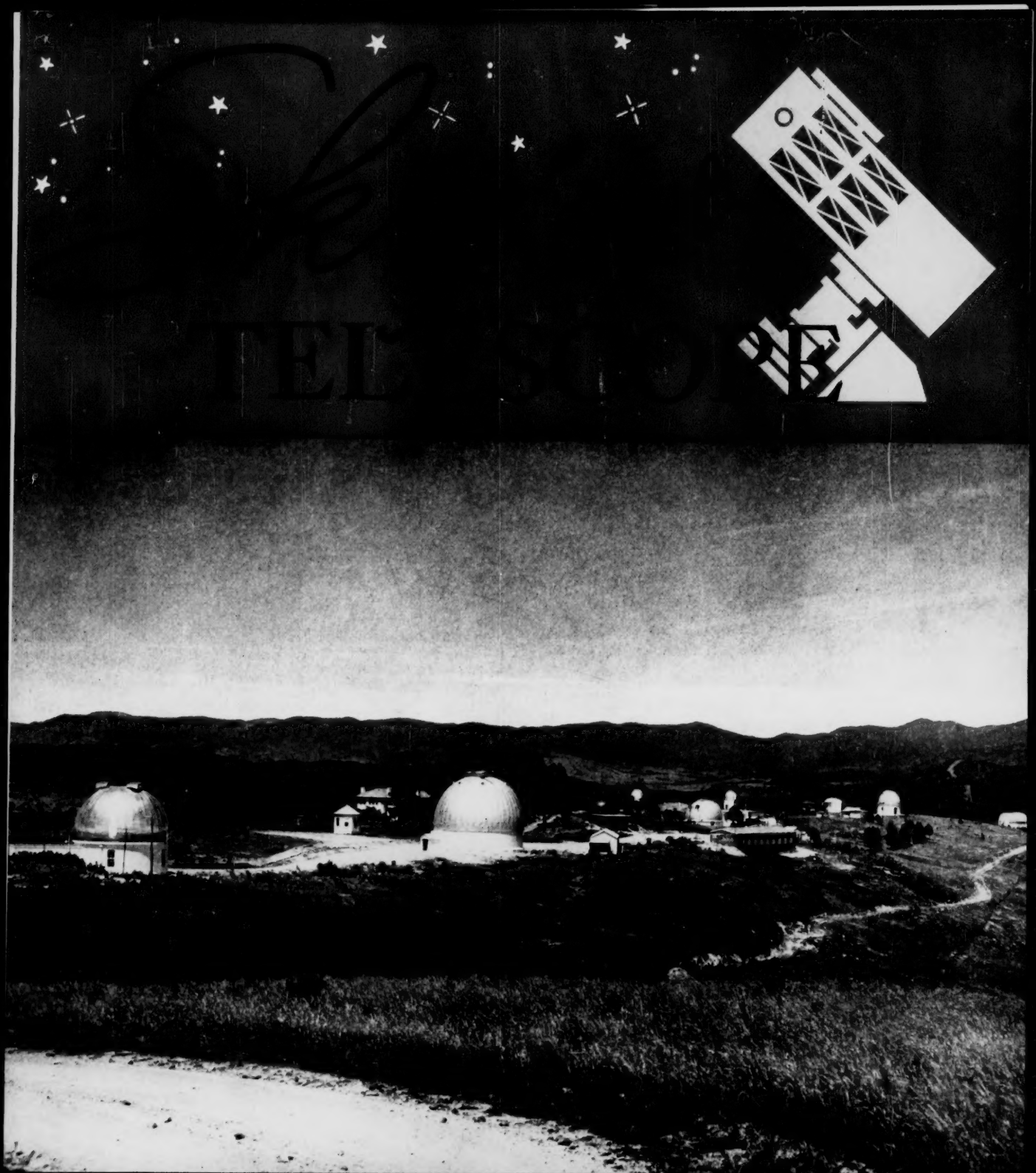

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Sky and TELESCOPE

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Vol. XV, No. 8 JUNE, 1956

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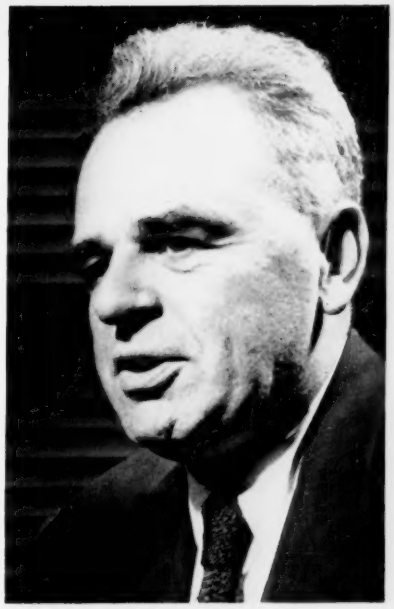


Bart J. Bok, of Harvard Observatory.

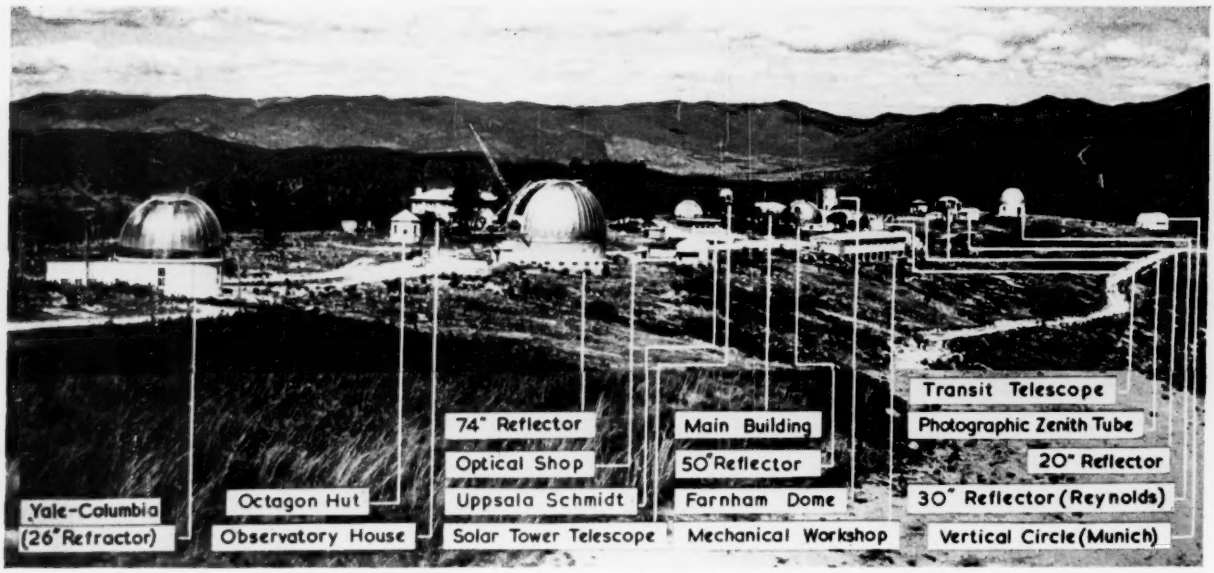
New Director for Mt. Stromlo

AN OUTSTANDING American astronomer has been named director of the Commonwealth Observatory in Australia. Dr. Bart J. Bok, of Harvard Observatory, will assume this post on February 1, 1957, succeeding Prof. R. v. d. R. Woolley, who has become 11th Astronomer Royal of England, in charge of the Greenwich Observatory at Herstmonceux.

The Commonwealth Observatory, on Mt. Stromlo near the Australian capital city of Canberra, is one of the best equipped in the world, as may be seen from the front-cover photograph and the pictures on pages 340 to 343 of this issue. There the new director will have excellent facilities for continuing and expanding the studies of the southern Milky Way on which he has been engaged for many years at Harvard.

Dr. Bok is an active leader in the relatively new field of radio astronomy, and at Harvard he and his co-workers have completed the installation of a new 60-foot parabolic antenna, at present the largest such instrument in the United States. At Mt. Stromlo, he will concentrate primarily on optical studies of galactic structure, working in close collaboration with the radiophysics laboratory at Sydney.

In addition to directing the Commonwealth Observatory, Dr. Bok will be professor of astronomy at the Australian national university in Canberra. He is at present R. W. Willson professor of astronomy at Harvard, and has been associated with its observatory since 1929.



This photograph is marked as a key to the front cover, which is a view of the Commonwealth Observatory on Mt. Stromlo, in Australia, as seen from the 9-inch Oddie refractor. Here, instruments of many sizes and types carry on studies of the southern skies, which are inaccessible to the large telescopes of the Northern Hemisphere. All pictures with this article are from the Australian Commonwealth Observatory.

The Australian Commonwealth Observatory

OLIN J. EGGEN, *Lick Observatory*

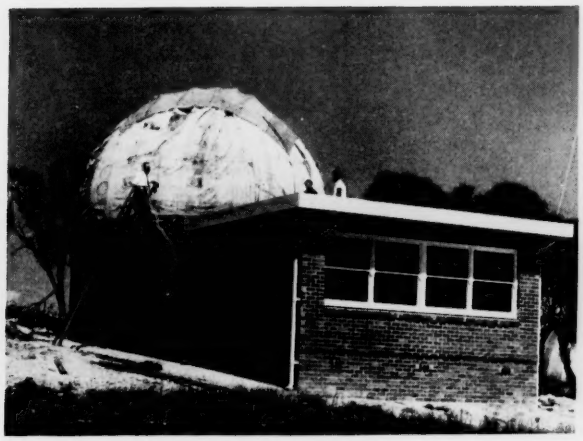
AUSTRALIA'S Commonwealth Observatory stands on Mt. Stromlo, about 2,600 feet above sea level in the Australian southern highlands, some 10 miles from the capital city of Canberra. The observatory is the best equipped in the Southern Hemisphere and, considering the light-gathering power and diversity of its instruments, it is one of the world's major astronomical institutions.

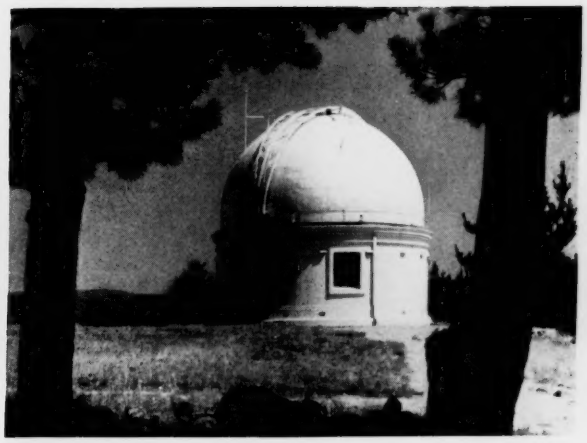
The workshop at Mt. Stromlo is one of the largest and best equipped of any observatory. Here much of the work for the 74- and 50-inch reflectors was done.

The astronomical history of Australia is, in a sense, older than its political history, for when Lieut. James Cook took the bark *Endeavour* out of Plymouth harbor in 1768, his "secret instructions" were twofold: to observe the transit of Venus at Tahiti and to look for "Terra Australis Incognita," the suspected great southern continent. Among the astronomical instruments on board was a clock that had just been returned from the American colonies, where it was used by two veterans of the previous transit of Venus, Charles Mason and Jeremiah Dixon, in surveying the Mason-Dixon line. When the *Endeavour* sailed into Botany Bay in 1770, that clock was used in the first astronomical observations, the determination of the longitude of what is now Sydney.

Eighteen years later, when the first permanent settlers came to the country, Capt. William Bligh, of *Bounty* fame and one of the early governors of the new colony, tells us: "Among the buildings that were undertaken shortly after arrival must be mentioned an observatory, which was built to receive the instruments sent out for the purpose of observing the comet that was expected about the end of that year (1788)."

Although the comet was not seen and the observatory soon fell into disuse,





Left: Workmen are completing the dome for the Schmidt telescope Uppsala Observatory is erecting at Mt. Stromlo. The Schmidt will have a 20-inch correcting plate and 26-inch mirror.

Right: The 30-inch Reynolds reflector, housed in this building, has done most of the observational work at the Commonwealth Observatory to date. It has a 3-prism spectrograph used at the Cassegrainian focus.

Australian astronomy had begun. During the next 100 years observatories were established in the states of New South Wales, Victoria, South Australia, and Queensland; the Perth Observatory in Western Australia was established in 1896. All of these were mainly concerned with time service and similar "government astronomy," but the names of many 19th-century astronomers in Australia are still familiar today. R. T. A. Innes, H. C. Russell, and James Dunlop did pioneer work in double stars; K. L. C. Rümker was noted for meridian astronomy; John Tebutt became famous for his comet discoveries.

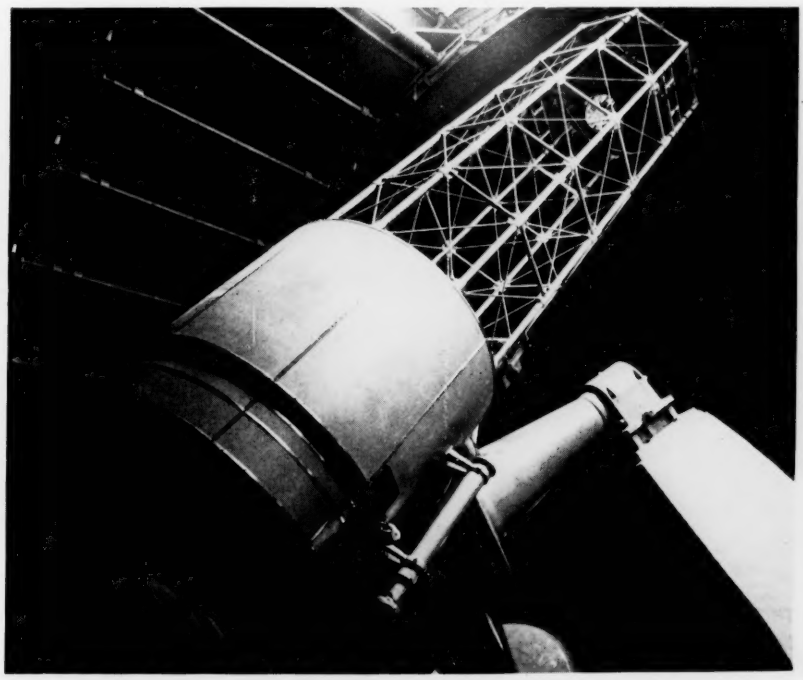
In 1903, fresh from his site surveys on Palomar Mountain and Mt. Wilson in California, W. J. Hussey, of the Lick Observatory, arrived in Australia to search out a suitable location for a 50- or 60-inch reflector. Acting for a committee of the Carnegie Institution, Dr. Hussey spent five months investigating sites in New South Wales, including the area that years later became the city of Canberra. But these early American plans for a large telescope in Australia did not materialize.

In 1905, soon after the establishment of the federal government of Australia, W. G. Duffield conceived the idea that eventually led to establishment of the Commonwealth Observatory. He was a young Australian science graduate attending the Oxford meeting of the International Union for Solar Research, when he was impressed with the fact that Australia could plug the longitude gap in the existing chain of solar observatories. Although he approached the government with supporting resolutions from the IUSR, the Royal Society, and the British and Australian Associations for the Advancement of Science, it was nearly 20 years before Duffield's proposal was put into effect.

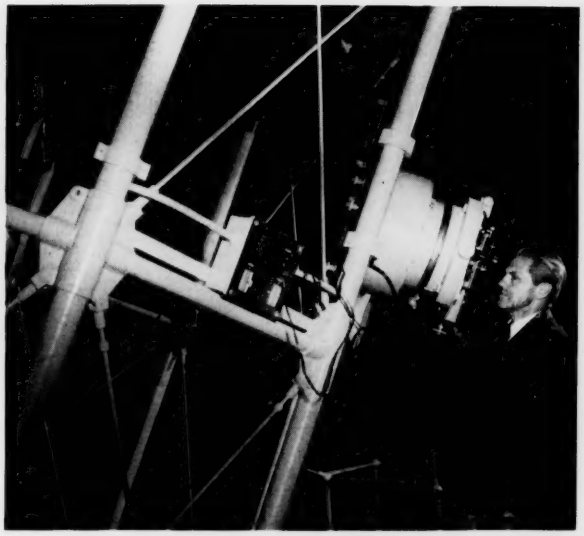
An Australian solar physics committee was formed in 1909 with Dr. Duffield as secretary, and the next year this committee accepted the first telescopes for the projected observatory: two Grubb refractors, a 6-inch from the estate of Lord Farnham, and a 9-inch from James Oddie of Ballarat. The Oddie telescope was mounted on Mt. Stromlo in 1911, and for two years the government astronomer of Victoria, P. Baracchi, carried out astronomical and meteorological observations there. He reported, "Taking into account all the circumstances, the site is decidedly suitable for an Astronomical Observatory of the highest order." The telescope was then "sewn up in cloth," where it remained for 10 years.

In April, 1922, the government definitely committed itself to building the observatory, and a committee of British astronomers was invited to select the first director. "It was as natural," wrote H. H. Turner, "that Duffield should be the first Director as that Flamsteed should be appointed the first Astronomer Royal. 'Who is to take charge of the new Greenwich Observatory?' said King Charles II. 'Why, the man who told you there was need of it.'"

Director Duffield opened the new Commonwealth Solar Observatory on January 1, 1924, but it was not until late in 1926 that the staff moved to Mt. Stromlo;



The 74-inch reflector has a mounting of the cross-axis type, which allows long exposures near the meridian and provides access to the celestial pole.

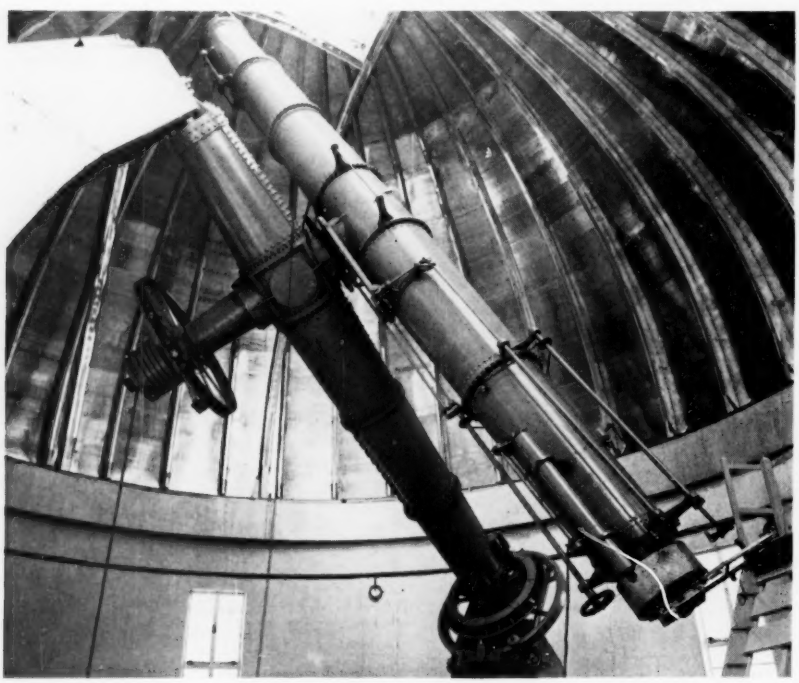


Left: The acting director, Dr. A. R. Hogg, a staff member at Mt. Stromlo since 1928, is examining the Gregorian focus of the 50-inch reflector. This instrument is a complete modernization of the first large telescope erected in the Southern Hemisphere.

Right: Dr. Woolley is shown at the 74-inch reflector, just before his departure to England to become Astronomer Royal.

when he died in 1929, the construction was not complete, although Duffield had the knowledge that his vision of 1905 had become a reality. For the next 10 years, W. B. Rimmer was acting director, work on the solar telescope was completed and a Hale spectroheliograph was installed.

It was during this period that the first large telescope was added to the observatory's equipment. Shortly after his appointment, Duffield had accepted the gift of a 30-inch reflector from J. H. Reynolds, but because of the pressure of other work the dome was not completed and the telescope erected until 1930. In recent years, the Reynolds reflector has been used by S. C. B. Gascoigne for photoelectric measurements of variable stars and clusters in the Magellanic Clouds. Also, over 250 plates of bright southern galaxies have been taken with this telescope by G. de Vaucouleurs.



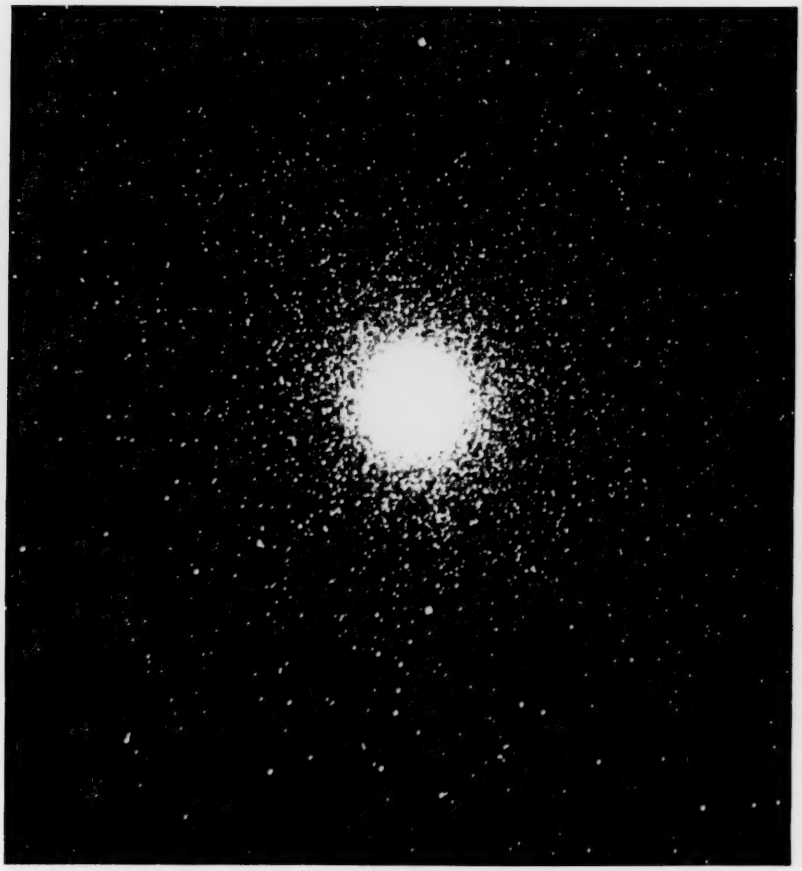
The Yale-Columbia 26-inch refractor has recently been moved to Mt. Stromlo from South Africa, where it was used since 1925 for measuring the trigonometric parallaxes of stars. The unusually fine f/16.5 objective was made by J. B. McDowell, of Pittsburgh.

On December 4, 1939, a new director, R. v. d. R. Woolley, arrived at Mt. Stromlo. He was formerly chief assistant at both the Greenwich Observatory and the Cambridge University Observatory. Almost immediately he laid down the concept that still governs the astronomical programs, to utilize the great possibilities for astrophysical research that are inherent in the observatory's location. Unfortunately, all plans were forestalled by the war, and from 1940 to 1944 the observatory was literally transformed into an optical munitions factory.

When scientific work was resumed late in 1944, the word "Solar" was dropped from the title, the director became the Commonwealth Astronomer, and the way was clear for the expansion program that is apparent in the accompanying photographs, and which is still continuing.

The first step in this new growth was the acquisition in 1944 of the historic "Great Melbourne Reflector," which has been transferred from the discontinued observatory at Melbourne, Australia. The original mirror (1868) of speculum metal has been replaced by a 50-inch spherical glass mirror of shorter focal length, and a 30-foot dome has been erected. Set up as a Gregorian, but not quite finished, the instrument is already being used for photoelectric work.

Next, in 1947 the Commonwealth government approved the purchase of a 74-inch reflector with dome and observing platform from Grubb Parsons and Co., Ltd. This instrument, which was completed in 1955, is the seventh in the world of 72 inches aperture or larger to go into operation, and only one other, the 74-inch at Pretoria, South Africa, is in the Southern Hemisphere. These two reflectors are almost identical. The new telescope has a focal length of 30 feet, and its moving



This photograph of the globular cluster 47 Tucanae was one of the first to be taken with the new 74-inch reflector of the Commonwealth Observatory. The mirror was used with a silver coating, as no aluminizing tank was then available. This fine cluster covers an area nearly four times that of the full moon; to the unaided eye it appears as a hazy star of about the 4th magnitude.

parts weigh some 40 tons. The 66-foot diameter, 100-ton steel dome can be turned by electric motors at one revolution in about five minutes, and the two shutters, weighing four tons each, can be opened in two minutes to expose the sky from the horizon to beyond the zenith.

The 74-inch mirror is coated with silver, but aluminizing equipment for this and the 50-inch mirror is being installed, and it is hoped that both mirrors will be coated with aluminum before July.

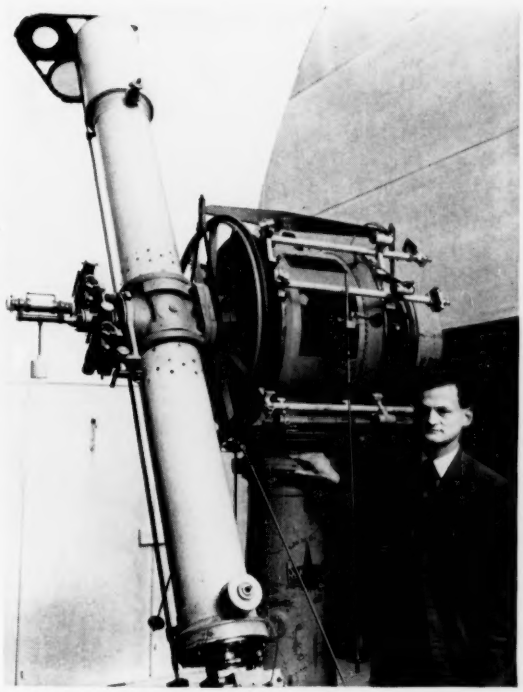
As part of its expansion program, the observatory has invited overseas institutions to erect instruments at Mt. Stromlo. The 26-inch Yale-Columbia refractor, famous for its work of measuring trigonometric stellar parallaxes, is now housed in a dome provided by the Commonwealth Observatory. At its original location in Johannesburg, South Africa, the 26-inch could be pointed only along a narrow strip of the sky near the meridian, but the telescope's mounting has been modified in the Mt. Stromlo workshops to eliminate this restriction. The first program plates with this instrument in its new location were taken on January 1, 1956, by Dr. de Vaucouleurs and Dr. Dirk Brouwer, director of Yale University Observatory.

Another dome has been provided for the 20-inch Schmidt telescope of the Uppsala Observatory, Sweden; it is expected to arrive sometime this year. A further addition was the Munich Observatory's vertical circle, brought to Mt. Stromlo by Dr. F. Schmeidler in May, 1954. He used it for precise determinations of the declinations of southern stars. This telescope has now been dismantled and returned to Munich, as the program was completed.

The buildings to house a 10-inch photographic zenith tube and its control equipment have been completed. The instrument, made by Grubb Parsons, arrived in Australia in the latter part of 1955.

Recent events have indicated that the observatory on Mt. Stromlo is entering a new phase of its development. Before his departure in December, 1955, to take up his duties as the 11th Astronomer Royal, Dr. Woolley pointed out the desirability of having the observatory associated with the new and rapidly growing national university rather than with the department of the interior, to which it has been attached for administrative purposes since its start.

Regardless of the final organizational arrangements, the wide variety of effective instruments at one site will make Mt. Stromlo an unusually versatile center of astronomical research, in solar work, stellar spectroscopy and photometry, galactic and extragalactic studies, and in precise positional work. Australian astronomers will continue to use the advantages of the Commonwealth Observatory's instruments and Southern Hemisphere location for the promotion of further astronomical knowledge.



Dr. Schmeidler stands beside the Askania vertical circle that he used at Mt. Stromlo. It is a visual 7-inch telescope with a finely divided circle for precise measurements of the meridian altitudes of stars, from which their declinations are deduced. In the complete observation of a star, pointings are made with the telescope both east and west of the pier. A similar instrument is in use at the Poulkovo Observatory in Russia.

NEWS NOTES

By Dorrit Hoffleit

HASTENING DARK ADAPTATION WITH COLORED GOGGLES

The effect of wearing colored goggles of different hues to reduce the dark-adaptation time for night fliers has been investigated by D. M. Polinsky and F. A. Young at the State College of Washington. Their results are presented in the February issue of the *Journal* of the Optical Society of America.

Under carefully controlled lighting conditions, each of the 10 subjects taking part in the tests wore red, green, or blue goggles for 2, 3½, 5, and 10 minutes. Then, with the goggles removed, the subject's dark adaptation was measured as the time that elapsed before certain faint, flashing light sources could be seen in an otherwise dark booth.

It was found that blue goggles had the least effect on subsequent dark adaptation. Exposure to either red or green light for 3½ to 5 minutes was effective in hastening adaptation for low levels of brightness, such as encountered both in night flying and astronomical observing. The adaptation curves following exposure to red light have steeper slopes for the first few minutes, but then level off and reach the lowest luminance levels in the same time as the green.

1,936 RADIO SOURCES

An extensive catalogue of radio sources, observed with the new radio telescope at Cambridge, England, has just been published in the *Memoirs* of the Royal Astronomical Society. The 1,936 sources, between declinations −38° and +83°, were observed at a wave length of 3.7 meters by interferometer techniques. The positions of the 500 most intense sources have an accuracy of two minutes of arc in right ascension and 12 minutes in declination. The 30 per cent of the sky too far south to be included in this survey is vacant in the chart.

Most of the sources are small: 30 have diameters between 20 minutes and three degrees. Sources with even greater apparent diameters, and those whose shapes suggest that they are part of the general galactic structure, are reserved for a later report. The 1,906 sources observed with high resolving power must all have diameters less than 20 minutes.

At least two types of sources are represented. The numerous small ones appear to be fairly uniformly spread over the sky, except for one remarkable grouping near the galactic anticenter. Large, intense sources, on the other hand, show a marked concentration toward the central plane of the galaxy. Large but less intense sources do not share this concentration; they might represent clusters of other galaxies.

Some 300 of the sources nearly coincide in position with optical objects, mainly galaxies, and statistical tests show that about 100 of these coincidences may eventually prove to be genuine. There are about 350 other sources with accurate positions for which optical counterparts have not yet been noted.

RADIO TELESCOPE ON PALOMAR MOUNTAIN

On April 10th a 32-foot microwave antenna began operation on Palomar Mountain in southern California, where the 200-inch reflector is located. The operation of this radio telescope marks the beginning of a long-term radio astronomy program by the California Institute of Technology, with support in excess of $400,000 from the Office of Naval Research.

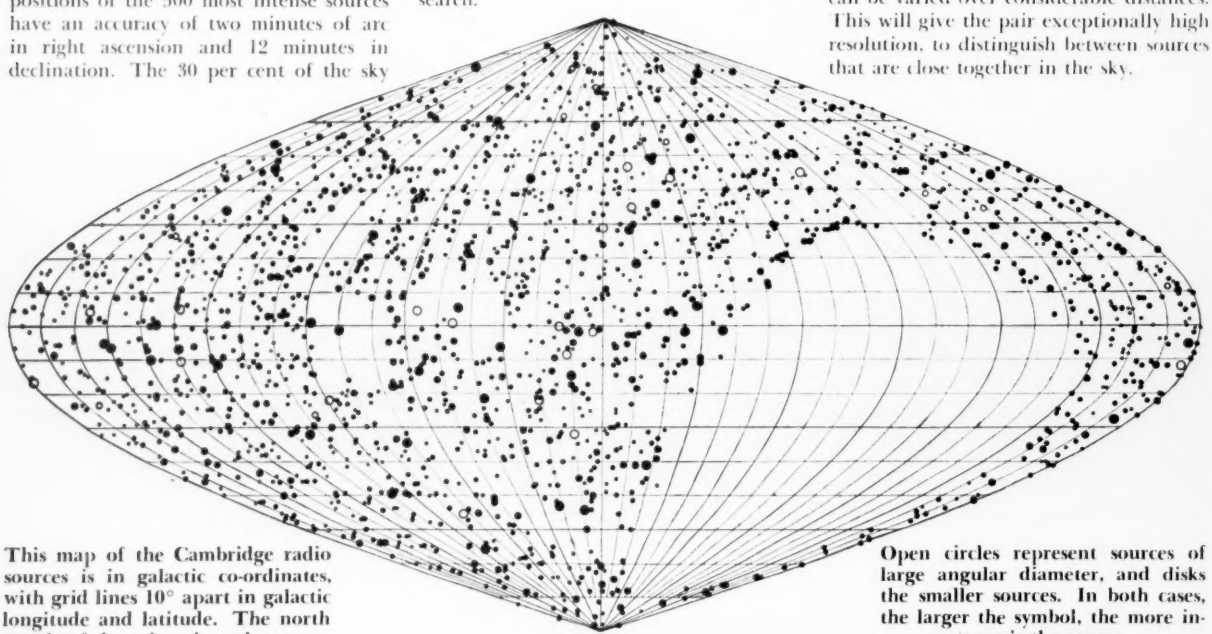
The new equipment will serve mainly as a pilot model and as a training instrument for astronomers and electronics personnel. Within another year, Caltech expects to mount three additional parabolic reflectors. One of these will also be 32 feet and the others 90 feet in diameter. The latter will be located on a California desert site, probably in the Owens Valley to the east of the Sierra Nevada range. This region offers extremely good protection against man-made radio interference and is reasonably near both Mount Wilson and Palomar Observatories.

The two larger reflectors will be steerable, and capable of tracking at the celestial rate. They are to be mounted on railroad flatcars on 1,600-foot tracks set in north-south and east-west directions and meeting at a point. Thus, they will be able to function separately, or to form together an interferometer whose spacing can be varied over considerable distances. This will give the pair exceptionally high resolution, to distinguish between sources that are close together in the sky.

IN THE CURRENT JOURNALS

THE PERIOD-LUMINOSITY RELATION OF THE CEPHEIDS, by W. Baade, *Publications*, Astronomical Society of the Pacific, February, 1956. "The determination of accurate absolute magnitudes of both cluster-type variables and type I cepheids remains one of the most urgent problems."

THE FORMATION OF THE PLANETS, PART I, by Gerard P. Kuiper, *Journal*, Royal Astronomical Society of Canada, March-April, 1956. "The age of the sun is close to 5×10^9 years, and hence essentially the same as that of the planets. This compels one to inquire whether the formation of the planets and of the sun cannot have resulted as parts of the same basic process, which must be that of stellar formation in general."



This map of the Cambridge radio sources is in galactic co-ordinates, with grid lines 10° apart in galactic longitude and latitude. The north pole of the galaxy is at the top.

Open circles represent sources of large angular diameter, and disks the smaller sources. In both cases, the larger the symbol, the more intense is the source.

VIRGINIA CONFERENCE

on the Cosmic Distance Scale

BART J. BOK, *Harvard College Observatory*

THERE ARE national and international scientific conferences of many varieties, and astronomy has had its share of them, both large and small. Some conferences attempt to summarize an area in which progress has been rapid and where evaluation is in order. Others select as their theme the development of research in a young field and consider plans for the future.

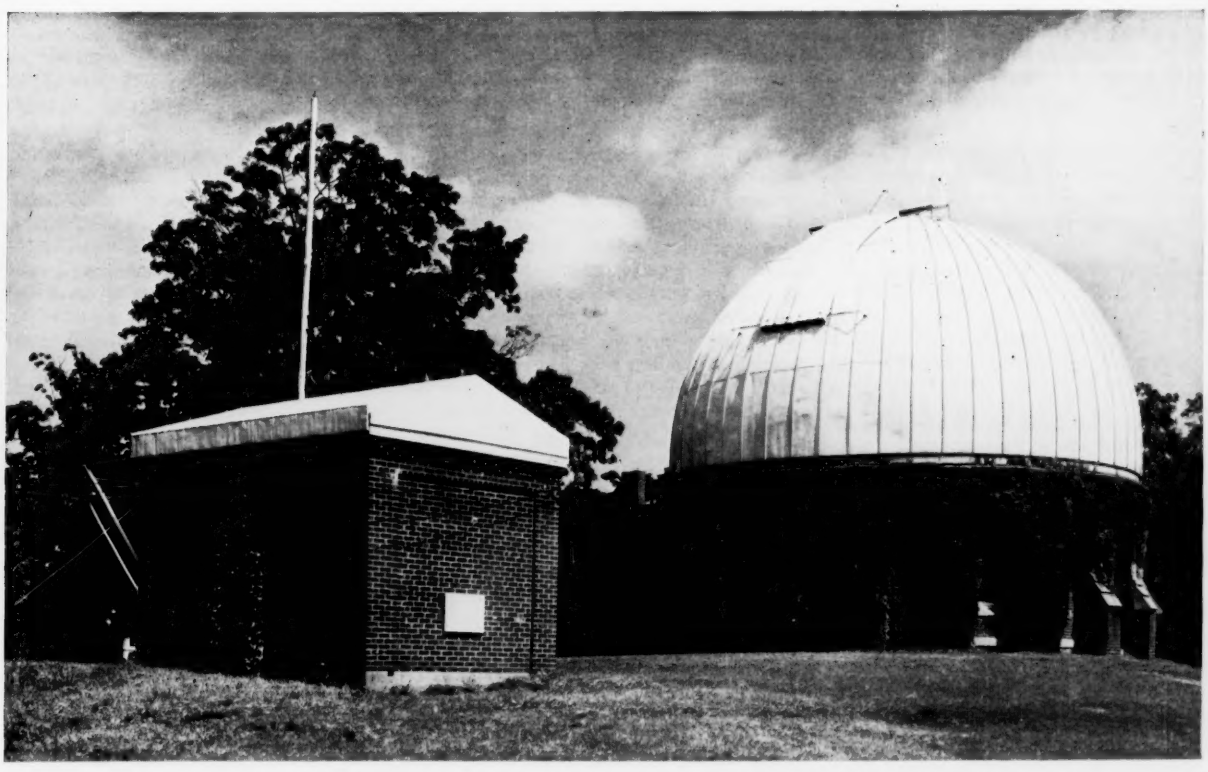
And then, once in a while, there comes the need for a conference of experts to sit down for a few days and do some real soul-searching. The Virginia conference on the cosmic distance scale was of this last variety. Therefore, my report may not make very encouraging reading. It deals mostly with difficulties, uncertainties, and with unsolved or half-solved problems.

To the student of astronomy who likes to have his universe served to him in a simplified, clear-cut and definite way, the results of the Virginia conference must seem unnecessarily indefinite and hazy. But although the participants in the conference, as much as any reader of *Sky and Telescope*, wanted to see the universe laid out in a simple and easily understood pattern, it would be far from the truth to say that all basic problems have been resolved.

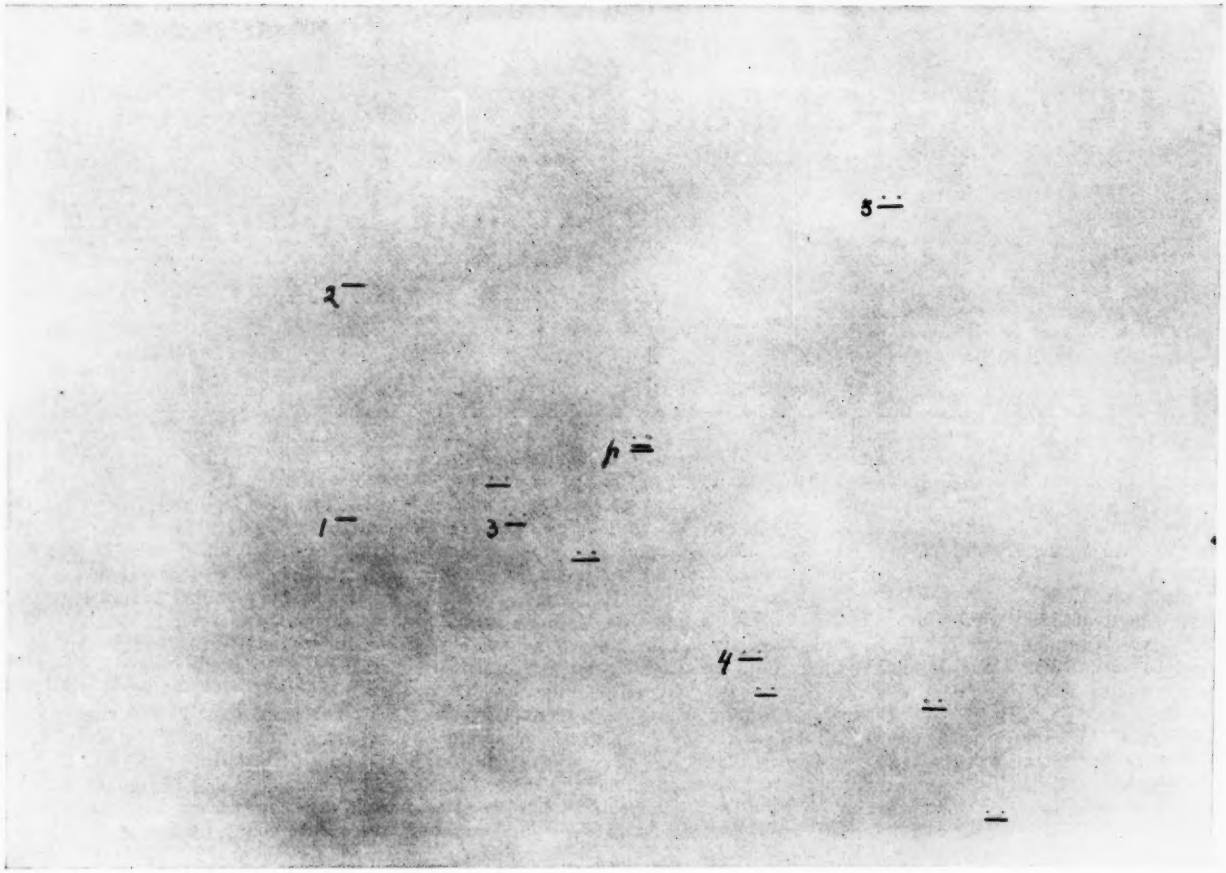
Nevertheless, the conference was a refreshing experience, and we all left it with a new outlook on the work that is still ahead of us. A grave responsibility for precise research rests, for instance, upon those of us who have or will soon have access to equipment in the Southern Hemisphere. Therefore, I have tried especially to tell of the *difficulties* we face in establishing the distance scale of our universe. To have been a witness to struggle and honest argument, to see progress come is a greater privilege than to be a witness only after the battle has been won.

The first plan for holding the Virginia conference originated with Peter van de Kamp, of Sproul Observatory at Swarthmore College. The conference was organized by the National Science Foundation under a committee headed by J. J. Nassau, of the Warner and Swasey Observatory, and the University of Virginia was our host. It was a closed conference, with not more than 35 astronomers in attendance, and it lasted for three full and busy days, starting April 5th.

Three major aspects of cosmic distance work were covered, one each day. First, we considered the fundamental scale of distances established for stars close to the



At the University of Virginia, the Leander McCormick Observatory's dome contains the 26¼-inch Clark refractor used to measure stellar parallaxes; in the other shelter is a 10-inch camera employed in the classification of stellar spectra.



Distance measurements of nearby stars are made from parallax plates such as this, taken with the 20-inch refractor of the Van Vleck Observatory, Wesleyan University. Two five-minute exposures give the double set of images; those for Sirius are doubly underlined. To facilitate measuring its position with reference to selected background stars (1 to 5), the brilliant light of Sirius was dimmed 10.5 magnitudes (about 16,000 times) by a rotating sector. Ordinarily, a parallax determination is based on more than 20 such plates, taken at intervals over several years.

sun by trigonometric parallaxes, by statistical studies relating to proper motions and radial velocities of nearby stars, and through research on moving clusters. On the second day, we studied the broad problems of absolute magnitudes and spectral classes, as well as the uncertainties in other tools used for exploration of galactic structure. Finally, we turned to the problem of the distance scale for the universe of galaxies.

The Distance Scale to 500 Light-years

It may come as a surprise to many readers that the liveliest discussions on the first day centered upon the systematic errors of trigonometric parallaxes, which are our direct means of getting star distances, using the earth's orbit as a baseline. The proper technique for parallax measurement by photography with long-focus telescopes was worked out 50 years ago by Frank Schlesinger for the 40-inch refractor at Yerkes Observatory. His method has served us very well, but the time has come to examine the feasibility of different approaches to the problem.

Our published lists of trigonometric parallaxes continue to grow. In 1904, 55 reliable stellar distances were known, whereas in the latest Yale catalogue (1952) there are 5,822 stars with known trigonometric parallaxes. But there are unexpectedly many cases of disagreement among the parallaxes of individual stars measured at different observatories, and even more worrisome are the sizable systematic differences between lists of parallaxes for groups of stars measured at several places. J. Schilt, Columbia University, and K. A. Strand, Northwestern University, were especially outspoken on the subject. The former pointed to some cases of very large differences, noting that the most uncertain quantity is probably the correction that must be applied to each individual parallax for the average parallax of the background stars relative to which the actual measurements are made.

Dr. Strand recommended that the minimum number of photographic plates for a trigonometric parallax worthy of inclusion in published catalogues should be 16, and that 35 plates for one star is a desirable goal. Dr. Schilt urged experimentation in measuring stellar parallaxes relative to faint and very remote external galaxies.

Problems of mean or statistical parallaxes came in for much attention; at Virginia's Leander McCormick Observatory some of the finest research in this field has been carried on, and is by no means finished. Our knowledge of mean parallaxes for faint stars comes largely from analyses of the average *reflex* of the sun's own motion as shown by the proper motions of groups of stars in various parts of the sky. To obtain reliable averages of solar motion reflex, the *secular parallaxes*, we must have measured proper motions that are remarkably free from systematic errors.

Papers by A. N. Vyssotsky, McCormick Observatory (who with Emma Williams Vyssotsky has been the principal contributor in this field), and by O. Heckmann, of the Hamburg-Bergedorf Observatory, demonstrated amply the continuing great need for high-caliber fundamental positions and proper motions of basic reference stars.

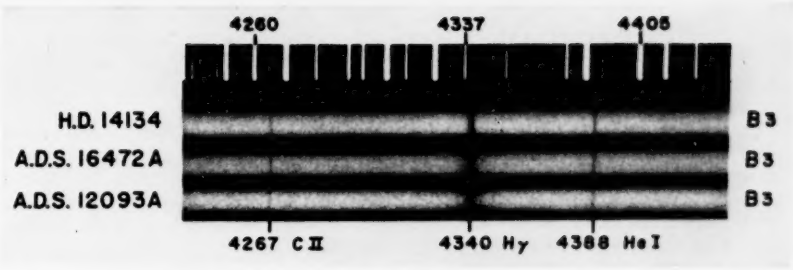
To obtain a reliable proper motion for a star requires precise positions at rather widely separated epochs. For many stars

we have recent positions of good quality, but the older positions, observed several decades ago, leave much to be desired. Hence, there is real need for completely new large-scale projects for the measurement of basic stellar positions, such as that being undertaken by Dr. Heckmann and his colleagues.

Instrumentation continues to be important in the minds of astronomers working on the distances and motions of the stars. The Virginia conference resolved to ask the National Science Foundation to construct soon, in the Southern Hemisphere, a refractor similar to the 20-inch astrograph now in operation at Lick Observatory (see *Sky and Telescope*, August, 1954, page 335). It is proposed to mount the new instrument in Australia, where it would be operated by the Yale-Columbia southern station. This proposal has already been discussed widely, with general approval by interested astronomers.

The Virginia conference also made a new proposal for a long-focus precision 60-inch reflector designed primarily for astrometric work: trigonometric parallaxes, positions and proper motions, measurements of double stars—all for faint stars between the 13th and 18th magnitudes. The design of such an instrument for position work free from systematic and other errors presents many problems, notably in the mounting of the mirror and the rigidity of the telescope tube, but there is every reason to suppose that these can be overcome. A careful preliminary engineering study seems in order.

We ended the first day with the chastened feeling that much remains to be done in establishing stellar distances within 500 light-years of the sun. D. Harris, Yerkes Observatory, showed that, even for the familiar nearby star clusters, there remain considerable distance uncertainties. The cluster that is fixed best is the Hyades, at close to 130 light-years from the sun. But for another favorite, the Pleiades, values between the extremes of 250 and 400 light-years have been found.



Here are portions of the spectra of three B3 stars, whose absolute magnitudes, from top to bottom, are −5.8, −2.0, and −0.4, respectively. The narrower the hydrogen-gamma (Hγ) line, the more luminous is the star. Dominion Astrophysical Observatory photograph.

From 500 to 10,000 Light-years

On our second day we moved far and wide through the Milky Way system. The primary problems are precise spectral classification and the assigning of absolute magnitudes to the stars thus classified. We also considered the related problems of star colors and space reddening. Throughout the day we were chiefly concerned with the distances of the blue-white *O* and *B* stars—giants and supergiants that have been found to be the most brilliant objects that outline the spiral pattern of our galaxy.

The original system of precise spectral classification goes back about 70 years to the work of E. C. Pickering, Antonia C. Maury, and Annie J. Cannon, at Harvard. But their original Henry Draper system did not distinguish between giants and dwarfs of similar spectral class. During the 1920's the additional factor of absolute magnitude began to enter the picture, and just before the second world war the work of W. W. Morgan and his associates at Yerkes Observatory gave us certain criteria to distinguish five or six subclasses of absolute magnitude for each spectral group.

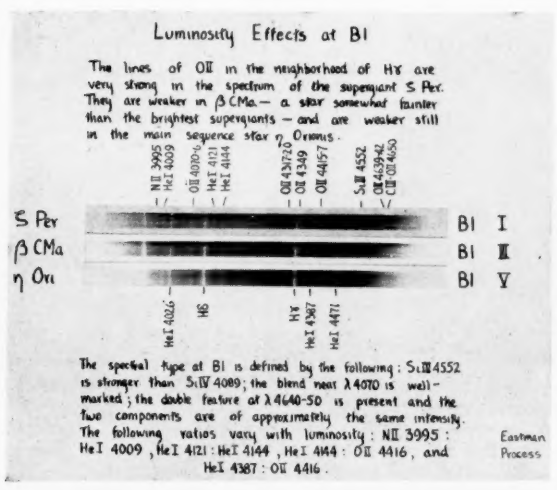
One of our problems, then, was to list the most probable mean absolute magnitude of a star with a certain spectrum and luminosity class in the Yerkes system, and to make estimates of the reliability of these standard absolute magnitudes. We also considered how we might combine the best features of the principal competing systems of spectrum and luminosity classification. In this work we felt at a serious disadvantage because of an international matter that threw a shadow on the conference.

The conference-planning committee had invited two European guests to attend, Dr. Heckmann from Germany and Daniel Chalonge from France. The former is one of the world's experts in fundamental star positions and motions, and he has done much on colors and motions of stars in clusters. His presence at the conference meant a real contribution, as we have already indicated.

Dr. Chalonge is one of France's top astrophysicists; he and his colleagues have developed a system of classification of stellar spectra, involving both temperature and luminosity, that has many novel features and that clearly required careful consideration by the conference. But there was a visa problem in his case because of his membership in a French organization for the promotion of cultural and scientific relations between his country and the Soviet Union. After many delays, he was granted a United States visa for only three days instead of the three weeks he sought, and therefore did not make the voyage at all. In this way the Virginia conference lost one of its potentially most useful participants.

Three competing systems of luminosity classification were considered: The Yerkes system is based principally upon variations in the intensity of luminosity-sensitive pairs of spectral lines. The Victoria system, developed by R. M. Petrie at the Dominion Astrophysical Observatory, uses the total intensity of the hydrogen-gamma line as an index of the absolute magnitudes for *O*, *B*, and *A* stars. The Chalonge system is the third one, for which the principal criteria considered by the conference are the extent of the drop in intensity at the Balmer limit and the measured wave length in the violet at which this drop has reached its halfway mark (*Sky and Telescope*, March, 1954, page 147).

The conference seemed to favor a proper blending of the three techniques:


Luminosity Effects at B1
The lines of OII in the neighborhood of Hδ are very strong in the spectrum of the supergiant ζ Per. They are weaker in β CMa — a star somewhat fainter than the brightest supergiants — and are weaker still in the main sequence star η Orionis.
NII 3995
HeI 4009
OII 4070-76
HeI 4121
HeI 4144
OII 4317-20
OII 4349
OII 4417
SiIII 4552
OII 4638-42
CIII OII 4650
ζ Per
β CMa
η Ori
B1 I
B1 II
B1 V
HeI 4026
Hδ
Hγ
HeI 4387
HeI 4471
The spectral type at B1 is defined by the following: SiIII 4552 is stronger than SiIV 4089; the blend near λ 4070 is well-marked; the double feature at λ 4640-50 is present and the two components are of approximately the same intensity. The following ratios vary with luminosity: NII 3995 : HeI 4009, HeI 4121 : HeI 4144, HeI 4144 : OII 4416, and HeI 4387 : OII 4416.
Eastman Process

The Yerkes system of spectral classification is illustrated by this typical page from "An Atlas of Stellar Spectra," by Morgan, Keenan, and Kellman. The designations I, III, and V, are luminosity classes of supergiant, giant, and main-sequence stars, respectively. The reproduction is to about half the original size.

the total intensity of the hydrogen-gamma line and the drop at the Balmer limit are considered to be important supplementary criteria to the Yerkes system of dependence upon line ratios.

Ascertaining the precise intrinsic brightnesses of stars in the various spectral and luminosity classes is one of the most difficult tasks facing astronomers to date. For the very important *O* and *B* stars, the basic method of distance measurement by triangulation fails entirely because there just are no normal stars in these classes close enough to obtain trigonometric parallaxes with anywhere near the required percentage accuracy.

Attacking the problem in a variety of ways, Dr. Petrie has made use of visual and eclipsing binaries with one component an early *B* star and the other a normal star of spectral class *A* or later (bright enough to permit a determination of its absolute magnitude and hence the distance of the pair). Second, he has studied the reflex of the solar motion in the proper motions of the *B* stars and equated it to the known reflex of the familiar motion of the sun of 20 kilometers per second with reference to the stars in our neighborhood as a whole. Third, he has derived distances from the apparent motions of *O* and *B* stars as affected by the rotation of the galaxy. All three methods yield absolute magnitudes for the most luminous of these stars that are about half a magnitude fainter than those assigned by the Yerkes group.

An independent study along somewhat different lines has been performed by A. Blaauw at Yerkes. He has concentrated upon *O* and *B* stars that belong to moving clusters, groups of stars with parallel motions in space, and has found a new and very disturbing effect. For a certain fixed spectrum and luminosity class, in several moving clusters and associations of stars the outlying members are more brilliant intrinsically than those inhabiting the denser—and often dust-rich—central parts of the cluster or association; the derived absolute magnitudes were, of course, corrected first for effects of interstellar absorption. Since the stars in the central region are probably the younger ones, it may turn out that our attempts to fix the distance scale with the aid of precision spectral classification may have to take into account unknown age factors.

Obviously, we must continue our efforts to measure accurately the spectra, luminosities, and colors of stars in galactic clusters. The current status of this work was summarized with skill by Dr. Harris. In almost every cluster we find certain stars for which absolute magnitudes can be fixed by the conventional spectrum-luminosity classification. We are then able to search, especially among the very bright *O* and *B* stars, for effects that may be attributed to the age of the cluster or to partial exhaustion of certain species of atoms through nuclear transformations. We must deliberately hunt for criteria in stellar spectra that are sensitive to precise chemical composition; finding them may make it possible to solve the age problem in spectrum-luminosity classification.

Our Galaxy and Beyond

During the final day, we moved to outer space to consider primarily the varieties of variable stars that are of first importance in establishing the distances of the Magellanic Clouds and neighboring galaxies. We started off on a reassuring note about the interstellar medium in our home galaxy. A. E. Whitford reported that recent work by him and his associates at the University of Wisconsin has confirmed the conclusion by a French astronomer, Mlle. L. Divan, that the law of space reddening within our galaxy is probably very nearly uniform. This is good news indeed, for earlier results seemed to suggest that for certain sections of the Milky Way the dependence of reddening on wave length differed considerably from the general average.

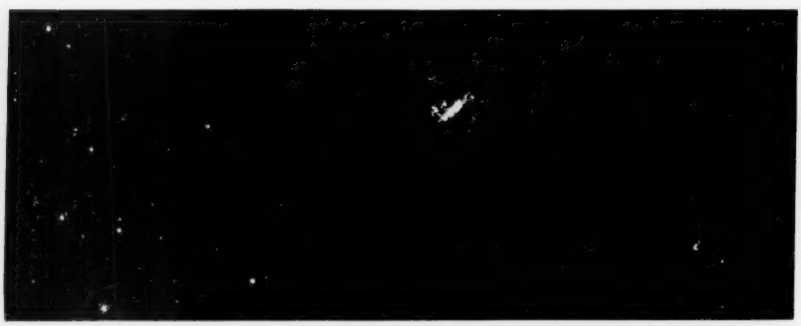
Dr. Whitford did, however, warn all of us against making the rash assumption that our galaxy's law of space reddening applies to the Magellanic Clouds or to the Andromeda spiral. He urged careful investigation of the reddening properties of the cosmic dust inside these galaxies.

The concluding hours of the conference were devoted to those pulsating variable stars that are so important as distance indicators in the universe: cluster-type and classical Cepheids, W Virginis stars and other type-II Cepheids. From the Mt. Stromlo Observatory in Australia (O. J. Eggen and S. C. B. Gascoigne) and from Mount Wilson and Palomar Observatories (A. D. Code) came evidence that the classical Cepheid variables in our galaxy are probably all considerably reddened and that the only reasonably unreddened stars of this type are observed in the Magellanic Clouds.

These neighbor galaxies and the globular clusters associated with them are more and more becoming the key objects for sorting out the absolute magnitudes of the confusing varieties of variable stars with Cepheid-like light curves. Some of these stars, with Population I characteristics, are found in the sun's region of the Milky Way, others of Population II are observed in the central and halo regions of galaxies, in the dwarflike systems such as the Sculptor cluster, and in globular clusters. W. Baade, of Mount Wilson and Palomar Observatories, surveyed this whole complex field, so full of contradictions.

The mean absolute magnitudes of the RR Lyrae variables, with periods of one day and less, seem to remain fairly well fixed at 0.0, corresponding to an intrinsic brightness about 100 times that of our sun. The classical Cepheids of Population I follow the old period-luminosity relation with a correction of about 1.5 magnitudes to the old zero point, and they are all luminous supergiants. Dr. Baade thinks that we may need two separate period-luminosity laws for variable stars of Population II, one for the type-II Cepheids and another for the W Virginis stars. He urges that the absolute magnitudes of these stars when at their minimum brightnesses—rather than at their mean between minimum and maximum—be considered the critical quantity to which each period is related.

Since most of the globular clusters, the brightest Sculptor-like systems, and the Magellanic Clouds are in the southern skies, there is a crying need for research in this field by Southern Hemisphere observatories. Recent work at the Radcliffe Observatory in Pretoria, South Africa, and at Australian observatories, has already proved of great importance, but the effort must be increased in the next few years. Dr. Baade pointed out that a reliable distance scale for extragalactic research can be obtained only if distance indicators of each variety can be studied in several of the types of stellar systems we have listed above. He mentioned further that the search for novae and the study of their light curves would prove very rewarding. This is indicated by recent work of H. C. Arp, first on the Andromeda galaxy at Mount Wilson Observatory, and now for the Magellanic Clouds at the Cape and Radcliffe observatories in South Africa.



The nearest neighbor galaxies to our own Milky Way system are the Magellanic Clouds, in the southern sky. This is a composite of Harvard photographs in which a part of the Milky Way is at the left, the Large Cloud is in the center, and the Small Cloud is in the lower right. The Clouds provide a vital link in the establishment of a scale for extragalactic distances.

On the Origin of the Solar System

OTTO STRUVE, *Leuschner Observatory, University of California*

MORE THAN 20 years have elapsed since the publication of Henry Norris Russell's thought-provoking book, *The Solar System and Its Origin* (Macmillan, New York, 1935). The closing sentences of that treatise read:

"We conclude, then, at last, that no one can yet say how our system originated in detail, but that we may reasonably regard its birth as the merest incident in a far vaster process,—the shaping of the material Universe as we know it. What lay behind that shaping we do not know. Our searching has brought us no nearer the Power whence all things proceed than did Job's colloquy with his friends. But one who has attempted to set out in order what little we have learned or may surmise may hope, at least, that his endeavors may seem less destructive and even perhaps more profitable than those of Browning's poet and philosopher, who had

" . . . written three books on the soul,
Proving absurd all written hitherto,
And putting us to ignorance again."

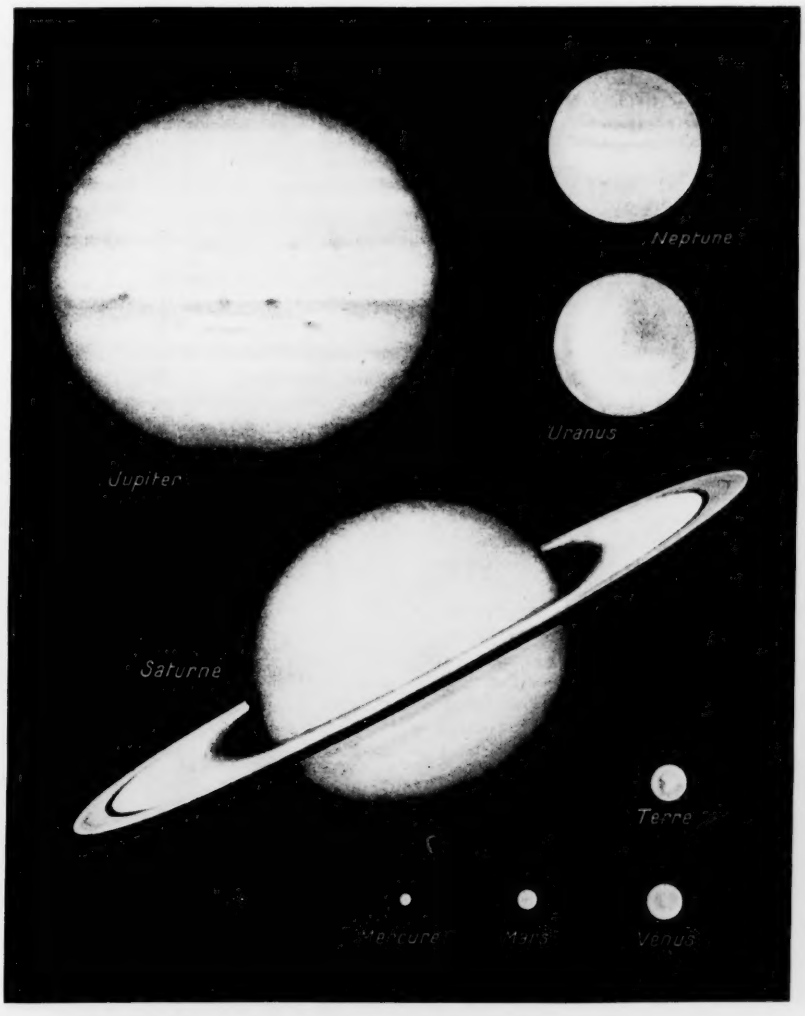
We are still far from having a satisfactory theory of the origin of the solar system. Nevertheless, great progress has been made in the past 20 years in clarifying some of the processes that must have played an important role in producing the planets. Undoubtedly, every astronomer has thought about this problem, and a long list of them have made significant contributions. We shall mention only a few of these many advances, particularly the ideas of G. P. Kuiper at Yerkes Observatory, and V. A. Krat of the Poulkovo Observatory in Russia.

The nebular hypothesis suggested by Laplace in 1796 attributed the formation of the planets to the condensation of gaseous rings shed (as a result of centrifugal instability) by the contracting and cooling sun. This theory was demolished by the successive efforts of J. Babinet in 1861, who showed that the planets possess far too much angular momentum; of M. Fouché in 1884; and of F. R. Moulton in 1900. And Russell in 1935 emphasized that the principal planets, while having less than 1/700 of the whole mass of the solar system, carry 98 per cent of the angular momentum. The sun, with nearly all the mass, contains only two per cent of the angular momentum.

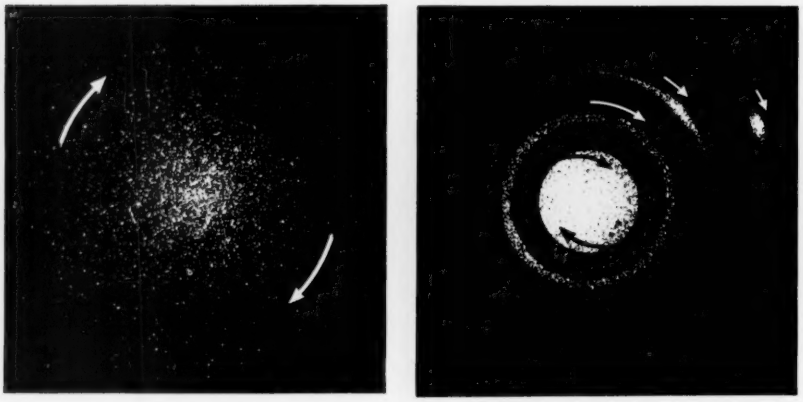
We can think of the angular momentum as the amount of rotation in a system, counting both the spinning of a body around its internal axis and its revolution in an orbit. In the latter case, for instance, the angular momentum is the product of the mass times the square of its distance from the center of revolution times the angular velocity around that center.

Laplace's theory demands that the central body carry the greater amount of rotation; at the time a ring separated, the layers just inside it, which remained attached to the sun, had almost as much angular momentum per ton as did the ring. But the mass of the inner layers must have been much larger than the mass of the ring. Hence, if Laplace were correct, the total angular momentum of the sun would always have remained larger than that of the planets.

This argument against Laplace has lost some force because it is now realized that



The principal planets of the sun's family differ greatly in size and appearance. Pluto is not included in this drawing reproduced from "Astronomie," by Rudaux and de Vaucouleurs, Librairie Larousse, Paris, 1948.



Laplace's proposal for the formation of the planets from the sun.

the sun's rotation may have been greatly slowed after the formation of the planets by the braking action of the sun's magnetic field; this field would interact with the interplanetary particles remaining from an original solar nebula. This idea is due to H. Alfvén. It pictures a rapidly rotating sun whose magnetic field turns with the main body. Ionized particles outside of the solar atmosphere, revolving around the sun in accordance with Kepler's third law, tend to fall behind the lines of force. But, being electrically charged, these particles find it difficult to cross the lines of force and are dragged along by them. Hence, the particles tend to be accelerated —angular momentum is transferred to them from the sun until the angular velocity of the sun is the same as that of the medium. The rotation of the sun is gradually reduced, that of the medium is increased. Nevertheless, it seems difficult to drain off enough of the sun's angular momentum in this way to save the nebular hypothesis.

Another weighty argument against Laplace's proposal has been stressed by Krat. The orbits of the planets are not in the same plane. For example, those of Mercury and Venus are inclined to the plane of the earth's orbit 7.0 and 3.4 degrees, respectively. And the earth's orbit (the ecliptic plane) is inclined to the sun's equator by 7.2 degrees. Laplace's nebular hypothesis requires that all the original inclinations must have been zero, but if the orbits had once been coplanar they would have remained exactly so—perturbations could not have produced the observed inclinations. Therefore, we must assume that the original orbits were not in the same plane, and this makes unacceptable any theory that attributes the origin of the planets to the centrifugal instability of a single rapidly rotating gaseous mass.

We need not discuss in detail the catastrophic theories, such as the planetesimal hypothesis of Moulton and T. C. Chamberlin, and the tidal theories of J. H. Jeans, H. Jeffreys, and others. These all require an extremely improbable event: a very close passage of another star through the domain now occupied by the planets. Moreover, W. J. Luyten and F. Nölke have proven that a filament of gas pulled out of the sun would dissipate rapidly because of gravitational forces; and L. Spitzer has also shown that the high temperature of the filament would make it disperse long before it could condense into planets.

The foregoing discussion has been chiefly destructive. On the constructive side, an important advance is Kuiper's realization, "It almost looks as though the solar system is a degenerate double star, in which the second mass did not condense into a single star but was spread out—and formed the planets and comets." Kuiper has investigated the frequencies of the semimajor axes of binary-star orbits in our galaxy. His diagram shows that they range between 0.01 and 100,000 astronomical units; their average is 20 units, quite similar to the average distance of the major planets from the sun.

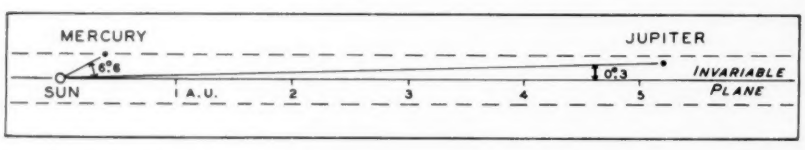
At the present time the total mass of the planets is roughly 1/1,000 that of the sun. But we shall see later that the original mass of the nebula out of which the planets were formed was at least 100 times as great, or 1/10 of the sun. In some 20 per cent of all double stars the smaller component has only 1/10 or less of the mass of the primary star. In Kuiper's words, "Since roughly half the stars are binaries one may say that about 10 per cent of the stars are attended by companions not over 0.1 times as massive. Several astrometric binaries with secondaries having masses between 0.1 and 0.01 sun strengthen the belief that binaries with large mass ratios are no exception."

We can leave aside the question of the precise mechanism that in some cases produces in a nebula two stars having masses of 1 and 0.1 sun, and in other cases a single star of solar mass and a system of condensations or *protoplanets* whose total mass is 0.1 sun. These contract to form the planets, but most of the original solar nebula is lost to interstellar space, and each planet is considerably less massive than its original protoplanet.

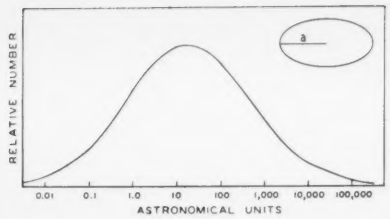
In any event, we know there are in our galaxy many *apparently* single stars like the sun. Nearly all of them have slow axial rotations. If single stars have developed from the contraction of suitable nebulosities, they must rotate rapidly in 99 cases out of 100. But in reality nearly all of them rotate as slowly as the sun does, as if they had experienced the braking action discussed by Alfvén. For this to happen, they must have been surrounded by a diffuse medium to which they could have transferred most of their angular momentum, and in such a nebulous envelope planets might have formed just as in the sun's case. Kuiper estimates that as many as one out of every 100 or 1,000 stars in the galaxy may have a family of planets. The formation of planetary systems is thus closely related to the origin of double and multiple stars, and even of star clusters. These latter processes occur frequently in the galaxy.

The inclinations of the orbits of the planets give us an indication that the solar nebula had an appreciable thickness at right angles to its plane of original rotational symmetry. This may be identified with what is called the *invariable plane* of the solar system at present. It represents the average for the system, and its orientation can be altered only by external forces. If the inclination of the orbit of any one of the planets changes as a result of perturbations, the inclinations of one or more of the other orbits must change in the opposite direction.

The innermost planet, Mercury, has the largest orbital inclination to the invariable plane (excluding Pluto), amounting to about 6½ degrees for a distance from the sun of 0.4 astronomical unit. A protoplanet in such an orbit would require a thickness for the solar nebula of about 0.1 astronomical unit. Farther out, say at Jupiter's distance of about five astronomical units, with an inclination of 20 minutes of arc to the invariable plane, the entire thickness would again be roughly 0.1 astronomical unit. Omitting Pluto from consideration (the outermost planet may formerly have been a satellite of Nep-



The dashed lines in this diagram represent schematically the limits to the thickness of the solar nebula, if Mercury and Jupiter are included within it at their present inclinations to the invariable plane. The angles are properly labeled, but the vertical scale is exaggerated for clarity.



This curve shows the relative frequency of the orbits of double stars with different values for the semimajor axis (defined by "a" in the inset diagram of a binary orbit). The diagrams on this page are adapted from the book, "Astrophysics," edited by J. A. Hynek, McGraw-Hill, 1951.

tune), we may assume that the original solar nebula had a thickness of 0.1 astronomical unit and a radius of about 30 units. Its volume would then have been about 10^{42} cubic centimeters. Were its total mass that of the planets today, about 2×10^{30} grams, its density would have been 2×10^{-12} grams per cubic centimeter.

The solar nebula may have been somewhat thinner than 0.1 astronomical unit; Kuiper makes it about five times less, thus increasing the density. Even so, the average density of the original nebula could not have been much greater than about 10^{-11} grams per cubic centimeter, *if* it contained the same mass as now found in the solar system outside the sun. In such a solar nebula, could a protoplanet have been formed as a permanent condensation?

To answer this question, we must consider one of the oldest problems of classical astronomy—tidal instability. Most astronomers are acquainted with the application of this problem to the stability of a satellite in the gravitational field of its planet, involving Roche's limit. The importance of this problem to the theory of the solar nebula was first clearly understood by Kuiper—he seems here to have made the most important advance since Russell in our understanding of the origin of the planets. We shall therefore discuss it in some detail, with the aid of simple mathematics.

Suppose we start with two masses of one gram each, m_1 and m_2, separated by a distance of one centimeter. Imagine them to be in free space, not gravitationally influenced by any other bodies, and initially at rest with respect to each other. Then, after the lapse of one second of time we shall observe that they are moving toward each other with a velocity of 7×10^{-8} centimeters per second; this is the value of their acceleration as a result of their mutual gravitation. Newton's law of universal gravitation can thus be written:

$$\text{Force} = 7 \times 10^{-8} \frac{m_1 \, m_2}{d^2} \text{ dynes.}$$

That is, the force is proportional to the product of the masses and inversely proportional to the square of the distance between them. This expression is all we need to discuss the problem of tidal instability, with the aid of the accompanying diagram.

The small circles at the right represent two temporary condensations, each of mass m grams and radius r centimeters. Their average distance from the sun is a centimeters. Could the two stick together by their mutual attraction upon each other they would form a permanent condensation. But the sun attracts the nearer more than the distant one, tending to pull them apart. Evidently, to remain tidally stable their mutual gravitation must be at least as great as the difference between the attractions of the sun upon them individually.

The attraction of the two condensations upon each other is $Gmm/(2r)^2$, or $Gm^2/4r^2$ dynes, where we have written G in place of the number 7×10^{-8}. If M is the mass of the sun, its attraction upon the nearer condensation is $GMm/(a-r)^2$ dynes, and upon the more distant one, $GMm/(a+r)^2$ dynes. The difference between these attractions is

$$GMm\left\{\frac{1}{(a-r)^2} - \frac{1}{(a+r)^2}\right\} \text{ dynes.}$$

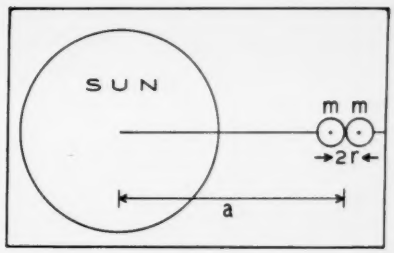
The factor between the parentheses can be shown by a little algebra to be $4r/a^3$, to a close approximation.

Therefore, the two condensations will just be able to resist separation by the sun's attraction, forming a stable system, if

$$Gm^2/4r^2 = 4GMmr/a^3,$$

or

$$m/r^3 = 16M/a^3.$$



Illustrating tidal instability, as applied to the formation of planets.

But the mass of each condensation (if it is spherical) is $m = 4\pi r^3 \varrho/3$, where ϱ is its density. Inserting this in the above criterion for tidal instability, we find

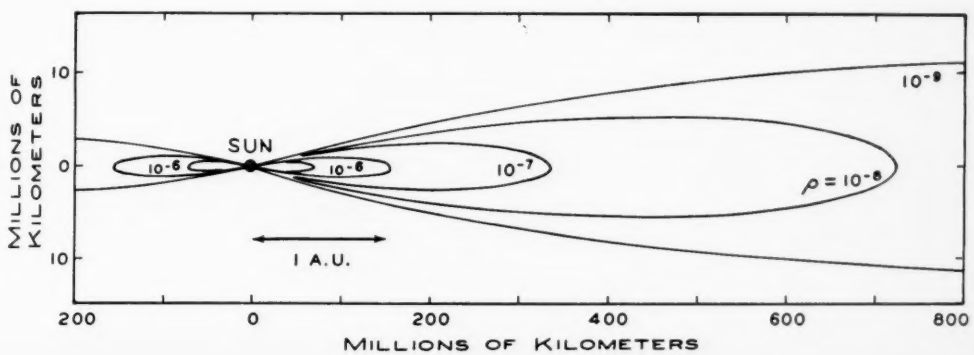
$$\frac{4\pi r^3 \varrho}{3r^3} = \frac{16M}{a^3},$$

or, pretty closely, $\varrho = 4M/a^3$.

Put into words, for condensations to be tidally stable the density of the solar nebula at a particular place must be greater than four times the mass of the sun divided by the cube of the distance from the sun. If the average distance is 10 astronomical units, or 1.5×10^{14} centimeters, and the mass of the sun is 2×10^{33} grams, this criterion tells us that to form a permanent protoplanet the density of the solar nebula must have been at least $4 \times 2 \times 10^{33}/(1.5 \times 10^{14})^3$. This is about 2×10^{-9} grams per cubic centimeter.

Compare this result with the density of 10^{-11} that we derived previously on the basis of the planets' present total mass. A likely way of closing the gap between these values is to suppose that the original solar nebula contained at least 100 times as much mass as do all of the planets now. What remains is only one per cent of the original mass; the other 99 per cent has escaped out of the solar system, probably in the same way that the earth lost most of its atmospheric hydrogen and helium. Kuiper has computed the actual distribution of the critical densities in the solar nebula, and his results are shown here.

A nebula of this kind is quite different from any of the familiar galactic nebulosities, such as the one in Orion. The latter has a density of the order of 10^{-20} grams per cubic centimeter. Neither can we



These are curves of equal density found by G. P. Kuiper in his study of the solar nebula. The vertical scale is 10 times the horizontal, so the nebula was actually much flatter than indicated here. The length of the scale arrow is one astronomical unit.

identify the solar nebula with B. J. Bok's dark round globules. Yet, since the formation of planetary systems is probably going on at present in the vicinities of many apparently single stars of the sun's type, we wonder whether other such solar nebulae should be visible through a telescope.

Seen from the earth at a distance of about 200 light-years (60 parsecs), a nebula with a diameter of 60 astronomical units would subtend an angle of about one second of arc. There would not be many stars near enough to show such nebulous disks, but spectroscopic effects might be observable. When seen edgewise, the path of light through the nebula would be so long that the opacity would render the central star invisible. But at right angles to their planes of symmetry, such nebulae would probably show emission lines, of hydrogen and possibly of other elements.

However, the lifetime of a solar nebula is relatively short—perhaps only a million years. Hence, even though many a star may have at some time during its extended lifetime been surrounded by such a nebula, we should not necessarily expect to find many of these nebulae at the present time.

We should probably search for such solar nebulae among relatively young stars with about the sun's mass. It is tempting to suggest that the T Tauri variables are such stars. Their spectra show emission lines almost certainly coming from nebulous shells or envelopes. Their absorption lines are often "veiled," as though the central stars were seen through fairly thick obscuring material. And their absorption lines are usually broad, as though the stars had not had time to get rid of their large initial rotational momentums. And some stars of the T Tauri type have apparently been forming in a region in Orion, where they are embedded in a minute nebula (*Sky and Telescope*, December, 1955, page 59).

Amateur Astronomers

Activities of the Detroit Astronomical Society

THE Detroit Astronomical Society has a membership of over 200 junior and senior amateurs. We meet on the second Sunday of each month, except in the summer, at State Hall, which Wayne University provides for our well-attended meetings. Educators from nearby universities are invited to speak on subjects related to astronomy, and at each meeting one of our members demonstrates his homemade telescope.

We have a mirror-making class which meets every Friday night in the basement of a member's home. About 15 grinding stands are used by the telescope makers, under the expert supervision of two members, Dr. D. Craig and G. Raths. Over 400 mirrors have been finished and about 150 telescopes mounted since the society was first founded, by six persons in 1933.

Our main yearly project is an exhibit at the Michigan state fair. It consists of several telescopes for public demonstrations and a tent which seats 40 persons to view astronomical movies. Another well-received feature is a camera obscura made by Mr. Raths. This exhibition costs us considerable money, but we feel we are repaid by the public's response, as thousands visit it.

Throughout the year, we also schedule public star parties at various city parks.

Our most noteworthy event over the years was a solar eclipse expedition in June, 1954, to Mellen, Wisc., in which about 20 members participated. The townspeople generously allowed us to use an empty farmhouse. We were located in an ideal spot, 1,370 feet above sea level and about a mile from the center of totality. To help repay the people of Mellen for their hospitality, our members decided to construct a telescope, which we hope to present to them soon.

This society is a member of the Astronomical League, its members having been active in its early stages of development, which included the historic Cranbrook convention of 1946.

JAMES C. PERRIN
3940 McClellan
Detroit 14, Mich.

PORTLAND, TENN.

We have a very active astronomy club here called the Portland Astronomical Society, with 25 members and two directors. There are seven telescopes in our club, the largest being a 6-inch reflector.

Our meetings are held at members' homes on the first and third Saturdays of each month, the second devoted entirely to observing. Dr. Albert Dittes is president; Donald Harris, vice-president; and the undersigned, secretary.

ROBERT O. RIGGS
Box 42, Portland, Tenn.

THIS MONTH'S MEETINGS

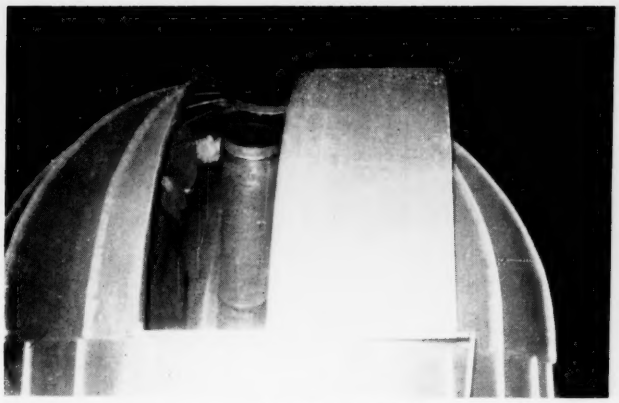
Chicago, Ill.: Chicago Astronomical Society, 8 p.m., Adler Planetarium. June 8, Dr. Herbert Hochberg, Northwestern University, "Ancient and Early Medieval Astronomy."

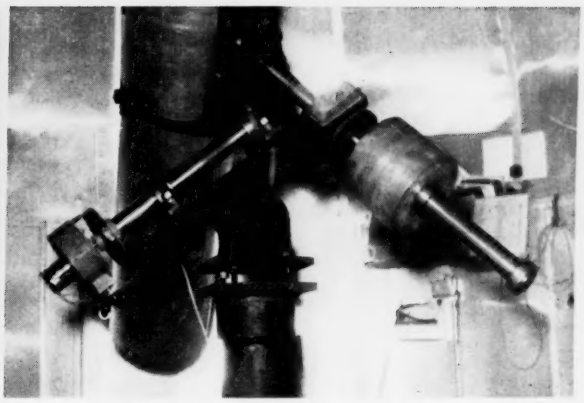
St. Louis, Mo.: St. Louis Astronomical Society, 8 p.m., Academy of Science. June 15, Dwight J. Ludden, Lick Observatory, "The 120-inch."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. June 2, Dr. Helen Hogg, David Dunlap Observatory, "The Globular Clusters—Beacons of Our Galaxy."

Whittier, Calif.: Whittier Amateur Astronomers Association, 7:30 p.m., Bailey School building. June 5, Thomas A. Cragg, Jr., Mount Wilson Observatory, "Variable Stars."

Junior members of the Detroit Astronomical Society helped conduct the exhibition at the state fair last year. The camera obscura is at the right. A mirror at the top reflects a portion of the landscape downward through a lens of long focus, which forms a large image on a screen or table inside the vertical tent. This image can be viewed by several persons at a time, as if they were inside a camera. Photograph by A. T. Evert.





At the left, an observer is using the 12½-inch reflector for star observations. Note the generous width of the shutter slot. At the right, the heavy mounting of this telescope is seen. The declination axle has a heavy counterweight, and there is a smaller one on the polar axle. Twin Ridge Observatory photographs.

Twin Ridge Observatory in Virginia

FROM THE TIME late in 1952 when we laid five cubic yards of cement for the foundation, our Twin Ridge Observatory project has been progressing. The first telescope in the dome was an 8-inch reflector, but that has since been replaced by a 12½-inch, and the 8-inch is now mounted in a small slide-off shed close to the large dome.

We have public school classes out several nights a week when school is in session. Boy and girl scouts are regular visitors, and we often have church groups. There have been crowds as large as 150 at a time, and when the weather is good there is nearly always someone visiting the observatory.

My son, Clyde, Jr., has worked with me on the entire project. We made three smaller telescopes before starting on the 8-inch. Both of us are members of the Richmond Astronomical Society.

The dome is 13 feet in diameter, and turns on a track at the floor. I laid out the plans and design, and a local sheet metal company did the finish work. Electric current is brought in underground.

When the 8-inch telescope was in the dome, we sometimes replaced it with a small homemade planetarium projector, and used the dome for the projection surface. Since the 12½-inch is too heavy to dismount, we either set the projector alongside or on the saddle of the telescope so that we can continue giving planetarium shows.

Our location is 3½ miles out of Richmond on the Midlothian Pike (U.S. 60W), close to the Sunset Drive-In Theatre, which I also own and operate. Whenever a group wishes to visit, we turn on a red beacon light mounted on our garage and visible from the pike. This signal serves as a location marker, and announces that the observatory is also open to the public. Traveling amateur astronomers from anywhere in the world are welcome to visit us at any time.

CLYDE O. CHILDRESS
R.F.D. 9, Box 135-C
Richmond, Va.

BLAIR MEDAL WINNER

Dr. Otto Struve, director of Leuschner Observatory, University of California at Berkeley, is this year's recipient of the G. Bruce Blair medal, to be presented at the Western Amateur Astronomers annual convention in August at Lowell Observatory, Flagstaff, Ariz.

Dr. Struve was selected for the award for "his constant encouragement of amateurs all over the world and his outstanding writing on astronomical subjects in a style suited to understanding by the amateur."

COLUMBUS, OHIO

Members of the Columbus Astronomical Society assisted with the local arrangements for the American Astronomical Society meeting in March at Ohio State University. Besides aiding with registration and the timing of papers, the society set up a display of telescopes and astronomical equipment. Included were a 10-inch reflector built by Jack Charlton, a 6-inch reflector owned by Sylvia Lane, a mirror of 12 inches being ground by Ivan Loftis for use in a Schmidt camera, and an elbow finder designed and constructed by Frank Hudnall.

GRAND RAPIDS, MICH.

Since its formation in December, 1954, the Grand Rapids Amateur Astronomers Association has grown to 40 active members, with some of its meetings attracting from 60 to 100 adults and juniors. The group, sponsored by the Grand Rapids Public Museum, meets at 8 p.m. on the third Friday of the month at the museum.

Among recent speakers at society meetings has been Ralph Baldwin, author of *The Face of the Moon*. In March members had a display of their telescopes and other instruments. Several star parties were scheduled for April.

James C. Veen, Sr., 2100 Francis Ave., S.E., Grand Rapids 7, Mich., is president of the society.

ROCKY MOUNTAIN CONVENTION

The Denver Astronomical Society will be host to the second annual convention of amateur astronomers in the Rocky Mountain states, to be held in Denver, Colo., August 4-5. Amateurs throughout the area are invited to participate and take advantage of a last-minute exchange of information and observing data before the Mars opposition this summer. Andrew Gassmann, 2256 Macon St., Aurora, Colo., can supply additional information.

The Rocky Mountain group, formed last year, is informally called the Mountain Astronomical Research Society, and is comprised mainly of members from clubs in Denver, Pueblo, and Boulder, and in Cheyenne, Wyo.

LOS ANGELES SOCIETY'S SUMMER STAR PARTIES

Several hundred observers will use some 50 to 75 telescopes in this summer's star parties scheduled by the Los Angeles Astronomical Society.

The parties, all on Saturday nights, will be held on June 9th, July 7th, and October 6th at the Casady Ranch about 14 miles from San Fernando; on August 4th at Mount Wilson Observatory parking lot; and on September 8th at the Menifee Valley Observatory.

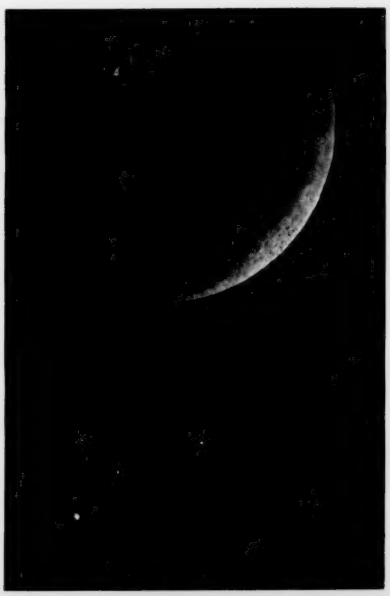
While at Mount Wilson, the amateurs will also inspect the 100-inch telescope. The trip to Menifee Valley will afford an opportunity to see the 18-inch reflector of Claude Carpenter, which is the largest amateur telescope in active use in the southwestern United States.

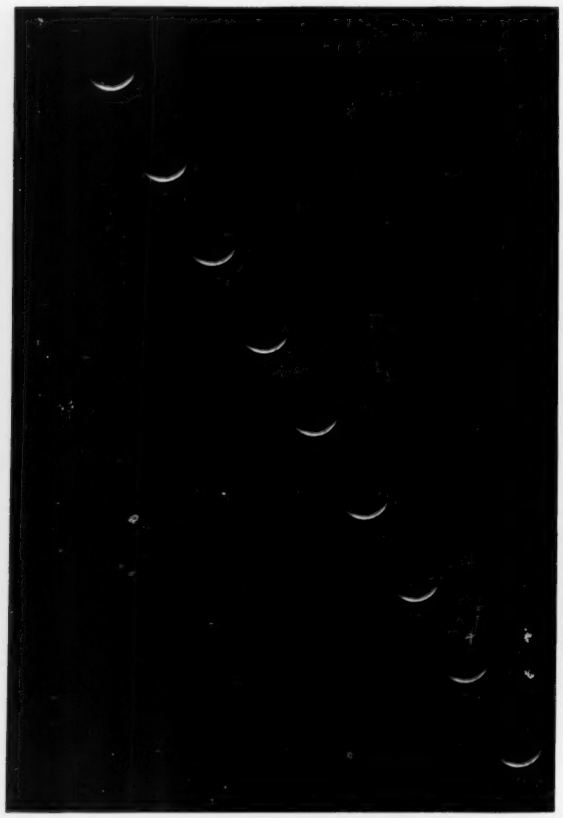
Further information about these summer activities may be had from Chalmers B. Myers, 1000 N. Seward St., Los Angeles, Calif.

Venus and the Moon on March 15th

On these pages are presented some of the photographs of the Venus-Moon conjunction on March 15th, received in response to the request on page 238 of the March issue, where the time schedule and other facts concerning the phenomenon are to be found.

Taken by Strathmore R. B. Cooke at Minneapolis, Minn., this picture was obtained at 8:00 p.m. Central standard time, with a Schmidt camera having a 10-inch mirror and 6-inch correcting plate, f/3.2. The exposure was one second on Eastman Commercial film, enlarged about nine times—through masks to bring out the earthshine on the dark part of the moon. The camera was mounted on a 12½-inch Newtonian reflector.





Left: Starting at 8 p.m., Pacific standard time, Leon Salanave, San Francisco, Calif., took an exposure of ½ second every four minutes. He used a fixed Wollensak 15-inch telephoto camera, f/11 on Kodak Commercial Ortho with a No. 12 Wratten filter.

Upper right: With his 6-inch homemade reflector, W. M. Tubby, Lewiston, Idaho, made this prime-focus picture. He stopped down to 3½ inches, using Panatomic X sheet film.

Lower right: These trails were made from 7:40 to 9:20 p.m. PST, at Pasadena, Calif., by Greg Smith. He set his Brownie Hawkeye camera on an altazimuth mounting he made from an old camera tripod and a loudspeaker. The film was Tri X.

FIFTY-THREE pictures in all were submitted, together with reports, from amateurs all over the country and in Canada. While the moon had set before the time of conjunction for eastern observers, those on the Pacific Coast were able to watch our satellite pass only about its own diameter north of Venus.

Several reports of visual observations have also come in. S. W. Bieda, Jr., San Jose, Calif., said his results agreed fairly well with the predicted distances of Venus from the moon. R. W. Heater, Walla Walla, Wash., and Frank Trathen, Napa, Calif., also watched the spectacle.

In addition to the pictures reproduced here, others were sent in by Harvey Dickey, Grants Pass, Ore., who used a 4 x 5 Graphic camera. Phil Brogan, Bend, Ore., sent a photograph by William Van Allen. Joan Brodovsky, Bill Boggs, and Bill McKeeman, University of California

At Albany, Ore., George Andrus used an f/5.6 aerial camera lens of 30-inch focal length; it was attached to a reflex camera, which aided in pointing at the conjunction. The exposure was 1/25 second at f/11 on Tri X film, at 7:30 p.m. PST.

Mr. Knox used a 35-mm. camera, Tri X film, with exposure times (from left to right) of 1/25 second, 1/5, 1/5, and 5 seconds, respectively, all at f/3.5. The prints are a 6x enlargement.

students, took pictures at Berkeley with an Argus C-3 camera and with a 4-inch Zeiss telescopic camera.

Edward Schmidt, Browning, Mont., reported that a slight cloud hazed the moon during the conjunction. The Laguna Beach Astronomy Club in California contributed a group effort. Five photographs were submitted by John E. Westfall, of Oakland, Calif. Philip Peters took photographs in Long Beach, while his father did the same at Camp Irwin, near Barstow, Calif. Chester L. Brown used an Argus camera on his Balscope Sr. telescope at Spokane, Wash.

Eastern contributors included Leon Lewis and Donald Aibel, of Brooklyn, N. Y.

The most northerly point from which pictures came is Kindersley, Sask., Canada, where John Knox, Jr., made a series of 12 exposures, of which four are shown above. There the moon passed closer to Venus than as seen from more southerly locations.

This beautiful spectacle will long be remembered. Although the moon passes Venus once a month on the average, so close an approach as this can seldom be seen against a dark sky.

Left: This series was taken by Robert Epstein on the roof of the Gleason Library at the University of San Francisco, at 15-minute intervals beginning at 8:15 p.m. PST. The first exposure was 15 seconds, and this was increased to 1½ minutes at the horizon. He used Eastman Plus X film with a 1-inch Rapid Rectilinear lens at f/7.

Right: Jim Peters, Seattle, Wash., used a homemade 3¼ x 4¼ camera with a Zeiss lens of 150 millimeters focal length for this series of the conjunction. Exposures were from one to two seconds at f/4.5 on Kodak Super Panchro-Press Type B.

ASTRONOMICAL SCRAPBOOK

Barnard's "Unexplained Observation"

NOWADAYS scarcely a year passes without the discovery of one or more novae, and it is probable that on the average one such star flashes up to naked-eye brightness annually. However, if you look at the lists of old novae, there are no well-authenticated discoveries between 1670, when Anthelm found Nova Vulpeculae, and Hind's detection in 1848 of a 5th-magnitude nova in Ophiuchus.

This gap of nearly two centuries was broken as recently as 1951, when Harold Weaver, of the Lick Observatory, presented convincing proof, by reobserving it, that a lost 6th-magnitude star recorded in the 18th century was actually a nova. In 1783 J. D'Agelet was cataloguing stars at the observatory of the École Militaire in Paris, and on July 26, 27, and 29 of that year measured the position of a star in Sagitta which later observers could not find. Weaver compared plates taken with the 60-inch Mount Wilson reflector in blue and red light, and found almost exactly in this position a 19th-magnitude star that was exceptionally blue and variable in brightness—two characteristic properties of a nova long past its maximum light.

This neat recovery stimulates hope that some other problematical cases can be established as old novae. There are indeed quite a number of reports of "lost stars," but for most the evidence is not above suspicion. The records are scanty, and ordinarily do not exclude the possibility of a blunder or misprint.

One very promising instance, of an object observed by Barnard in 1892, seems to have been generally forgotten by astronomers. Barnard's skill and care as an observer are proverbial, and the record is so clear and satisfactory that it seems likely this was a genuine nova whose remnant may still be identifiable in the sky.

In 1888 E. E. Barnard was invited to join the staff of Lick Observatory. Already he was famous as a planetary observer and discoverer of comets, of which he had found 10 while living in Nashville, Tenn. There in 1883 he had discovered the gegenschein (whose earlier finding by T. Brorsen in Europe attracted no attention), and there he had begun his pioneer photography of the Milky Way with fast, wide-angle lenses.

After his arrival at Lick in June, 1888, Barnard continued his photographic work, and was a regular observer with the 12-inch refractor. At first he was allowed only occasionally to observe with the great 36-inch telescope, then still the largest refractor in the world, but beginning in July, 1892, he obtained its regular use on Fridays. One of his first projects was a search for new satellites, which was spectacularly rewarded by the discovery of a fifth moon in Jupiter's system, on September 9th of that year.

Let us watch Barnard at work in the 36-inch dome on the night of August 12-13, 1892. There was the curious triple nebula NGC 6302, which Barnard had discovered 12 years earlier with his 5-inch refractor while comet hunting, and now wished to draw. Then he turned the telescope on Mars, to make micrometer measurements of its satellites. Next he observed Jupiter, timing an occultation of its second satellite, and examining the great red spot. Finally, in the morning twilight, Barnard turned to the planet Venus. In his own words:*

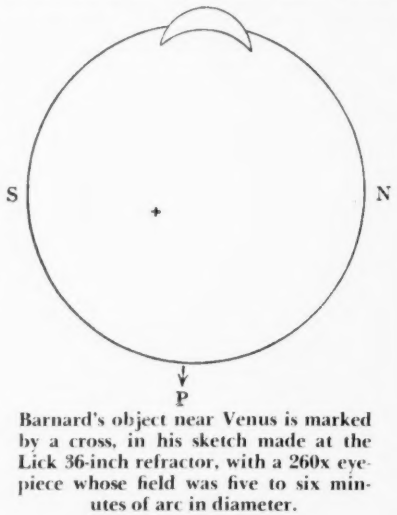
"I saw a star in the field with the planet. This star was estimated to be of at least the 7th magnitude. The position was so low that it was necessary to stand upon the high railing of a tall observing chair. It was not possible to make any measures, as I had to hold onto the telescope with both hands to keep from falling. The star was estimated to be 1′ south of Venus and 14″± preceding, at $4^h\ 50^m$ a.m. Standard Pacific Time . . . . [From this, Barnard deduces the position $6^h\ 50^m\ 21^s$, +17° 13′.6 for 1855.0.]

"There seems to be no considerable star near this place, and the object does not agree with any BD star.

"The observation was made in broad daylight, a half hour before sunrise."

Barnard could not identify the object. It was not an intramercurial planet, for the field was 38 degrees from the sun. The bright asteroids Ceres, Pallas, Juno, and Vesta, were all elsewhere in the sky, he pointed out. The starlike appearance of the image ruled out the possibility that it could have been a ghost of Venus.

Could there be a mistake in the date of his record, so the position of the object, referred to the moving planet, could now be altered to correspond to a known star? No, this doubt is definitely removed by Barnard's records of other phenomena timed on the same night.



Barnard's object near Venus is marked by a cross, in his sketch made at the Lick 36-inch refractor, with a 260x eyepiece whose field was five to six minutes of arc in diameter.

The account appears watertight, and the only reasonable assumption is that the 7th-magnitude star seen by Barnard was a nova, as F. J. M. Stratton has suggested. Appearing in the daylight sky, even a bright nova could have escaped ordinary detection, fading to inconspicuousness before this part of the sky again became accessible by night. The position observed by Barnard lies in the Milky Way in Gemini, a reasonable location for a new star.

If this interpretation is correct, it may well prove possible to identify the nova in the sky, by much the same procedure Weaver used to recover the new star of D'Agelet. Were a search with a large telescope to show a very blue variable star of about 18th to 20th magnitude in the location given by Barnard, astronomers would be able to add a Nova Geminorum 1892 to their list of reasonably assured new stars.

JOSEPH ASHBROOK

* The whole of the original evidence on Barnard's object can be found in *Astronomische Nachrichten 172*, 25, 207, 1906; *173*, 315, 1907.

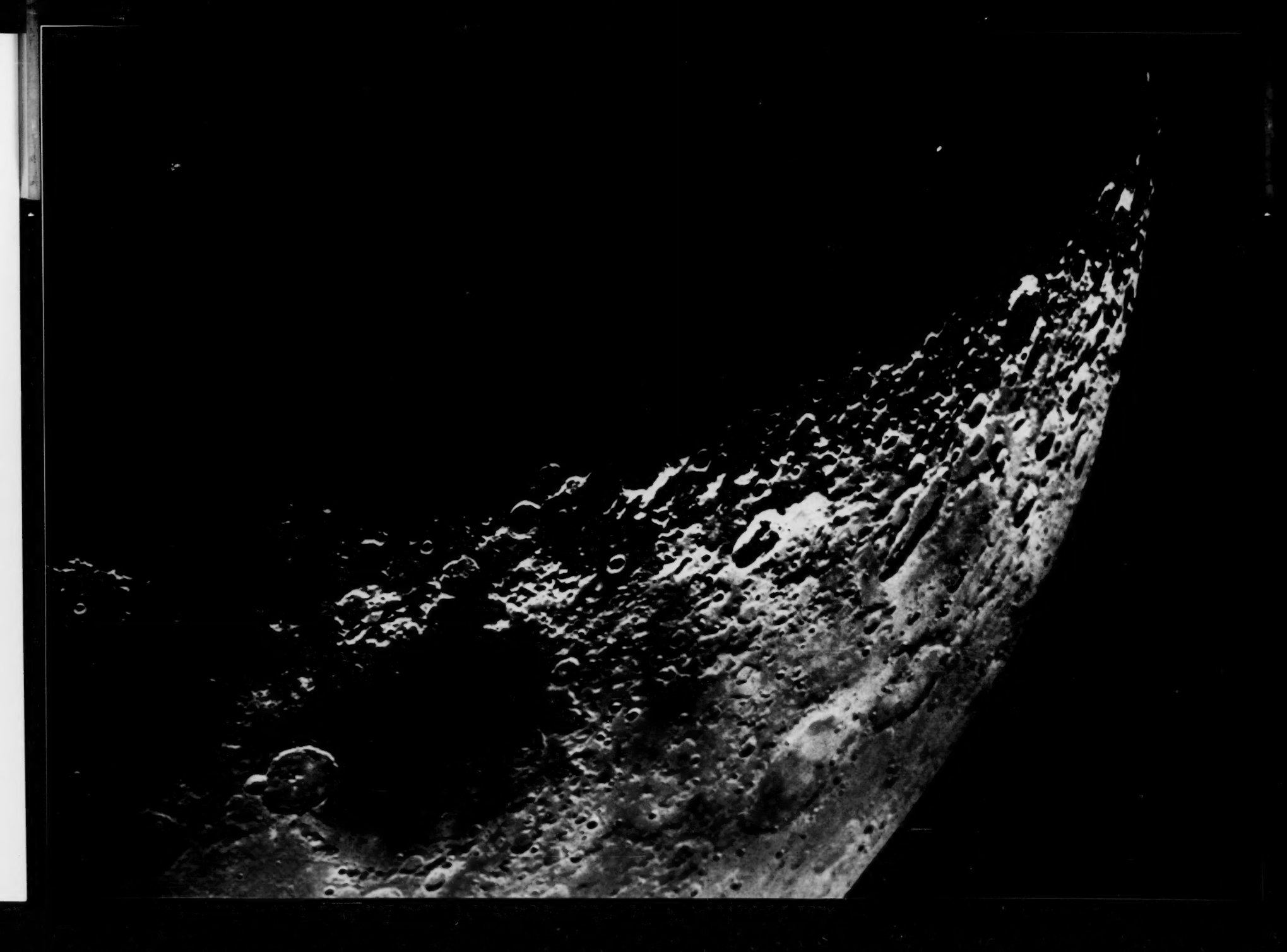
RADIO OBSERVATIONS OF THE COMA CLUSTER

For the first time, the 21-cm. microwave radiation of neutral hydrogen has been detected from very distant galaxies. David S. Heeschen has observed 21-cm. emission from the great cluster of galaxies in the constellation Coma Berenices, using the 25-foot radio telescope at Harvard's Agassiz station.

Operating the telescope at a fixed radio frequency, Dr. Heeschen could obtain a weak signal when the Coma cluster drifted across the direction in which the antenna pointed. By making such records at a number of frequencies, he determined the profile of the 21-cm. line. Its position corresponded to a red shift of about 7,000 kilometers per second, in good agreement with the optically measured value, 6,680 kilometers per second.

The radio observations indicate that the total mass of neutral hydrogen gas in the Coma cluster is about 10^{14} times the sun's mass. The distance of the cluster is about 75 million light-years.

FACING PICTURE: This is the fifth in a series of sectional views of the crescent moon. It shows the southern end of the morning crescent, enlarged from a negative taken by J. H. Moore and J. F. Chappell, with the Lick Observatory 36-inch refractor, on August 20, 1938. The age of the moon was 24.3 days. Earlier pictures in this series have appeared each month, beginning with February. Craters and other features can be identified from the lunar map in the January issue, now available separately as a reprint (see page 363 of this issue).



AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 94th meeting of the American Astronomical Society at Columbus, Ohio, in March. Complete abstracts will appear in the Astronomical Journal.

Radio Noise from Jupiter

The unexpected discovery last year that the planet Jupiter emits intense bursts of radio noise (see *Sky and Telescope*, June, 1955, page 324) continues to excite lively interest among astronomers. Three of the papers presented at the Columbus meeting reported new observations of the phenomenon.

K. L. Franklin and B. F. Burke, who originally detected the radiation from Jupiter, told of the systematic observations begun by the Carnegie Institution of Washington last November. Records at a frequency of 22 megacycles have been secured almost daily, for about seven hours a day. Periods of strong radio emission tend to recur at intervals corresponding to the rotation time of Jupiter valid for non-equatorial features (system II). This demonstrates that the source or sources are localized on the planet. Many of the records indicate that the radiation has strong circular polarization.

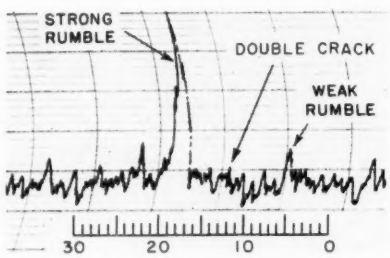
The Carnegie Institution radio astronomers are working in active co-operation with optical observers at Lowell Observatory and Mount Wilson Observatory, and with the Jupiter section of the British Astronomical Association, in an effort to identify the locations on the planet where the radio outbursts originate.

At Table Mesa, near Boulder, Colo., Roger M. Gallet, of the National Bureau of Standards, has been observing Jupiter simultaneously at 18 and 20 megacycles with two antennas. There are two types of signals: slow bursts, lasting two or three seconds, which give grinding sounds on a loudspeaker, and sharp clicks, some as short as 0.001 second, like those caused by terrestrial lightning. During the period that a disturbed region is on the nearer side of Jupiter, the signals occur intermittently, sometimes with an intensity exceeding any other radio source in the sky at these wave lengths.

Usually there is more noise at 18 megacycles than at 20, and individual signals observed at one of these frequencies are absent at the other. This must mean that single pulses contain only a narrow range of frequencies.

Dr. Gallet stressed the possibility of a detailed study of the ionosphere of Jupiter by radio methods. For example, if Jupiter has a magnetic field, its radio emission should be polarized by passing through the Jovian ionosphere. Moreover, as the planet rotates, carrying the radio source toward the edge of the disk, the signals should be cut off at a time that depends on the properties of Jupiter's ionosphere.

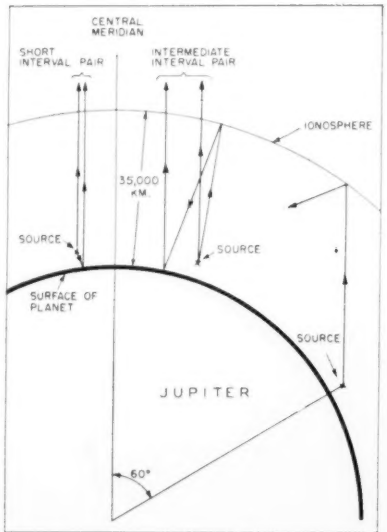
Strong radio emission occurs when



This record of radio noise from Jupiter was made at Ohio State University on January 20, 1956, the strong rumble occurring at 5:44 a.m. EST. The scale at the bottom is time in seconds, proceeding from right to left.

Jupiter's great red spot is on the nearer side of the planet, and Dr. Gallet suggested that this marks one of several sources of the noise. The relative fixedness and persistence of the sources on the planet argues against their being Jovian "thunderstorms"; instead, he envisaged disturbances at the surface of the planet that cause shock waves to spread outward through an ionized atmosphere, which would then emit radio noise.

The third paper was by J. D. Kraus, of Ohio State University, whose observations of Jupiter have been made with a radio interferometer working at 26.6 megacycles. He called attention to the fact that many of the short pulses observed from Jupiter are pairs or triplets, which fall into two groups. In one the clicks occur about $\frac{1}{4}$ second apart; in the other, the spacing is only a tenth as great. Dr. Kraus pointed out that this may be an echo phenomenon in which the second and third clicks are reflections of the first. Alternatively, these groups could be multiple electrical discharges, he suggested.



An electrified layer or ionosphere in the atmosphere of Jupiter may explain the occurrence of double clicks in its radio noise as echo phenomena. The depth of the ionosphere has been estimated from the clicks of $\frac{1}{4}$-second interval. This diagram is from Ohio State University.

In the photograph of a Jupiter noise record reproduced here, the double crack or pair of sharp clicks had a separation of about $\frac{1}{4}$ second. The actual peak intensities of these clicks was probably greater than that of the strong rumble, but their duration was only a few milliseconds, so the actual deflection, obtained with a recorder having a time constant of about $\frac{1}{2}$ second, is small. In a magnetic tape of Jovian radio noise that Dr. Kraus played back to the Columbus meeting, the rumbles were very deep and stentorian.

In the diagram, the Ohio State radio astronomer gives a possible explanation of pairs of clicks. Those with very short time between clicks might be from a source near the surface that was heard directly and by reflection from the surface. Pairs of longer intervals might involve echo phenomena from a reflecting layer (ionosphere) in Jupiter's atmosphere. The fact that the radio noise from Jupiter disappears before the source reaches the limb of the planet could be due to total internal reflection from the ionosphere, as shown for the source at the extreme right in the diagram.

Motions in a Star Cluster

A detailed study has been made by J. D. Fernie, Goethe Link Observatory, of the southern galactic cluster NGC 2547 in Vela, at right ascension $8^h\ 08^m.8$, declination $-49°\ 00'$ (1950). This cluster is an unusually loose one, about 37′ in radius, containing some 300 stars brighter than absolute magnitude +9, according to Mr. Fernie's work at the Cape and Radcliffe observatories in South Africa.

He has compared recent photographs of the cluster with others obtained 62 years earlier through the Cape 13-inch astrographic camera, to determine proper motions. Thirty-five stars showed an expansion of the cluster, nine a contraction, while the remaining 20 stars were either indeterminate cases or not members of the cluster at all. The time of expansion deduced from the 35 stars is only about 110,000 years—a remarkable result in that the cluster contains stars similar to those of the Pleiades, and is therefore presumably of about the same age, 50

million years. If this finding is confirmed, it would mean that the cluster has been expanding only during the last 0.002 of its lifetime.

Photoelectric measurements made by Mr. Fernie of the magnitudes and colors of stars in NGC 2547 give a preliminary distance to the cluster of 417 parsecs, considerably less than R. Trumpler's older value of 690 parsecs. The earliest spectral type represented is *B3*, while *A0* and *F2* stars predominate. An unusual feature of the color-magnitude array for the cluster stars is that the slope of the main sequence is smaller than normal.

Colors in Galaxies

At Tonanzintla Observatory in Mexico, G. Haro has been studying the colors of galaxies with the 27-inch Schmidt telescope. By taking three exposures on each plate, through violet, yellow, and blue filters, he has obtained photographs like the one at the right.

In this way, Dr. Haro has found that many galaxies have nuclei that are abnormally bright at short wave lengths. Spectroscopic observations of these objects show the occurrence of emission lines such as the forbidden line of ionized oxygen at 3727 angstroms.

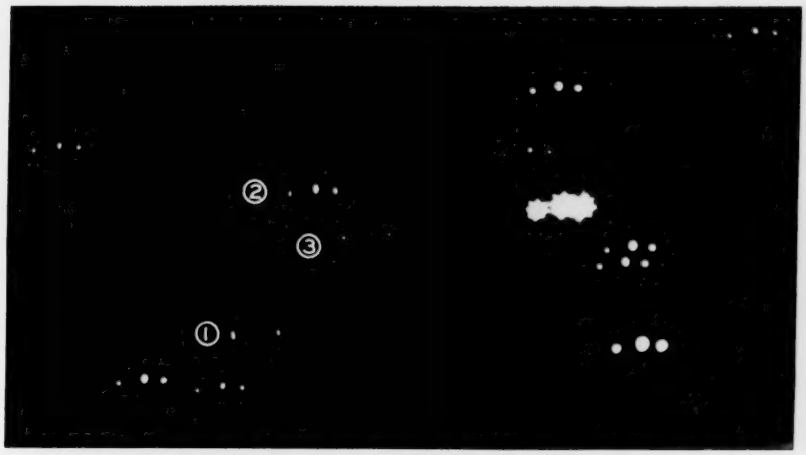
It has usually been assumed that the spiral arms of galaxies appear considerably bluer than their nuclei because the luminous blue stars of Population I are concentrated in the arms, while the nuclei consist of Population II stars. Dr. Haro suggests that his observations of galaxies with blue nuclei may require a revision of this conventional picture of the makeup of a spiral system.

Composition of Planetaries

The chemical composition of six planetary nebulae (NGC 1535, 2022, 2165, 2392, 2440, and 7662) has been determined by Lawrence H. Aller, University of Michigan Observatory, from spectrograms he secured with R. Minkowski at the 100-inch and 60-inch Mount Wilson reflectors.

The effects of filamentary structure of the nebulae, and the distribution of atoms among different stages of ionization, introduce complications that appear particularly serious for elements, such as nitrogen, that are observed only in the lowest stages of ionization. The effects of interstellar absorption upon the measured brightnesses of the spectral lines are also troublesome.

There is no convincing evidence of variations in composition from one object to another. The average for the six planetaries gives the following relative numbers for atoms: hydrogen, 17,000,000; helium, 1,350,000; oxygen, 10,000; nitrogen, 5,000; neon, 1,500; sulphur, 900; argon, 130; chlorine, 34; and fluorine, 4.



Galaxies marked 1, 2, 3, on this Tonanzintla Observatory photograph, are NGC 3991, 3994, 3995, respectively, each appearing (from left to right) in violet, yellow, and blue light. NGC 3991 has an abnormally violet nucleus. The overexposed images at the right are of a 6th-magnitude F-type star.

What Makes Meteor Trains Shine?

Sometimes as a bright meteor moves across the sky it leaves a luminous train. Most of the trains vanish quickly, but in rare cases this afterglow may remain visible to the unaided eye for an hour or more. It is known from radar observations that a meteor also generates a column of positive ions and electrons; furthermore, meteor spectra show that ionized atoms evaporate from the meteor during its flight. Therefore, it has been widely assumed by astronomers that the light of a meteor train is due to the recombination of ions with electrons.

A. F. Cook and G. S. Hawkins, Harvard College Observatory, find the foregoing explanation inadequate. Their calculations show that the recombination process could account for only about 1/200 of the observed brightness of typical meteoric trains. Consider, for example, a Perseid meteor that appears of magnitude −2.0 at a distance of 100 kilometers. One second after this meteor passes, a centimeter-long section of its train actually emits about 400 ergs of visible energy per second, but only a little more than one erg of this is due to recombination.

Hence there must be some other process that stores energy in the train and releases it as radiation. The Harvard astronomers suggest that this may be the formation of active nitrogen, which subsequently excites neutral meteor atoms in the train.

Comet Diameters

A major difficulty in understanding cometary physics is the shortness of time during which any one comet is under observation. Therefore, a statistical study of comets may give needed insight into the problems of their changing brightnesses and sizes, according to N. T. Bobrovnikoff, of Ohio State University.

He has analyzed nearly 7,600 observations of the dimensions of 300 comets. While the individual comets have had diameters from 6,000 to over a million kilometers, the average is 110,000 kilometers, or nine times the diameter of the earth. Moreover, the size of an individual comet varies as its distance from the sun changes; at 0.4 astronomical unit from the sun the average diameter is 79,000 kilometers, increasing to a maximum of 107,000 kilometers at 1.4 units, and then falling off to 54,000 kilometers at 4.7 times the earth's distance from the sun.

The most frequent average diameter for a comet is about 50,000 kilometers, but relatively few recorded comets are smaller than this. Evidently many small comets escape discovery, Dr. Bobrovnikoff pointed out, and the number of comets inside the orbit of Jupiter at any time may be far greater than the number actually observed.

In this Lick Observatory spectrogram of the planetary nebula NGC 7662, the bright image at the right is in hydrogen-beta light (4861 angstroms). The other images are due to ionized atoms of neon, helium, and oxygen.

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BOOKS AND THE SKY

ASTROPHYSICAL QUANTITIES

C. W. Allen. John de Graff, Inc., New York, 1955. 263 pages. $10.00.

HANDBOOKS that give readily available summaries of quantitative data are indispensable in most technical subjects. The *Handbook of Chemistry and Physics* is found on the desks of most workers in physical sciences, and vacuum-tube manuals are in every laboratory where electronic work is in progress. Astronomy has had no such general handbook in the past, but it has one now. In the future, *Astrophysical Quantities* will surely be found in the offices of every serious student of astronomy and of physicists and geophysicists whose work uses the numerical data of astronomy.

The book consists of 133 sections containing tables and lists of constants or conversion factors, and including a sufficient number of formulas and definitions to make the data readily usable. The numerical tables are not exhaustively subdivided. The author has intended to provide a sufficient number of data "to put the ideas of (each) branch of astrophysics onto a quantitative basis."

Astrophysical Quantities is divided into 15 groups of related sections. The first five contain general constants and units, both physical and astronomical, and the physical data of astrophysical interest under the headings of atoms, spectra, and radiation. We find ionization potentials, partition functions, atomic cross sections, a list of fundamental particles and their properties; spectroscopic terminology, terms, and electron configurations; multiplicities and oscillator strengths; definitions and interrelations of radiation quantities, absorption coefficients of atoms, and of stellar atmospheres as a function of wave length and electron pressure; tables of the Planck function, and more.

The remaining groups treat of the earth, including a number of tables, not found in most astronomy books, dealing with geology and with the upper atmosphere; the sun, planets and satellites, interplanetary matter, normal stars and special stars, stellar populations, interstellar space, clusters, and galaxies. In addition to the tables one might certainly expect in such sections, we find a list of the characteristics of faculae and granules, solar radio emission as a function of frequency for the quiet and disturbed sun, the atmospheric compositions of the planets, the brightness, color, and polarization of the zodiacal light, effective wave lengths of the common color systems of stellar photometry, distribution of stars with respect to rotational velocity, the characteristics and membership of Populations I and II, luminosity functions for the different spectral classes, characteristics of interstellar grains and gas, the radio temperature of different parts of the sky at a number of frequencies, quantitative features of the local star system, of clusters of galaxies, and of the universe as a whole. The book closes with tables for precession, conversion to galactic coordinates, and similar useful data.

The paragraphs above are by no means a complete listing of the contents of *Astrophysical Quantities*, but are intended to give some idea of the extent of its coverage. Many usually available tabulations are also included, as well as other more specialized ones. In short, with this book at hand, any representative numerical datum of astronomy can quickly be found.

The reader of this review will be tempted to say that the numerical specifications of many of the subjects mentioned above are not yet truly known. This is correct. Professor Allen has given the best values to date. One function of a book of this sort is to point out the places where additional observations are sorely needed. In the preface, the author states that he expects users to insert penciled amendments "to suit later results or to agree with their own opinions."

We should expect that the volume will be revised every few years. In a general way it appears that references have been complete to 1953, and there are a number to the literature of 1954. The references at the end of each section often lead to

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survey and summary articles, and a user unfamiliar with a particular branch of astronomy will be led first to these, from which he can branch out to the more specialized original papers.

Astrophysical Quantities is a reference book, and there is no effort to teach relationships that the reader does not already know. Most amateur astronomers may find relatively little in it of use to them. Astronomy majors and graduate students, however, will find careful thumbing through it very helpful. When they reach the stage where they are familiar with a problem to which each of the tables may be applied, they will have a fine working knowledge of astronomy.

ROBERT FLEISCHER
Rensselaer Polytechnic Institute

EXPERIMENTS IN THE PRINCIPLES OF SPACE TRAVEL

Franklyn M. Branley. Thomas Y. Crowell Co., New York, 1955. 119 pages. $2.00.

MANY educators and scientists are sharply aware of the fact that space exploration will shortly become a reality and that space travel will probably be achieved not long afterward. Some of us feel that the Columbus of 1992 has already been born and may be in our classrooms now.

Children even more than adults are ready for the idea of space travel. They show a wonderful interest and readiness for learning about it, but their background is too much composed of television space adventures, movies, and science fiction. None of these mediums is likely to provide a foundation of sound facts. Parents and teachers who realize this are likely to pick up Branley's book with real hope, since its purpose is "to enable the reader to differentiate between science and fiction and provide a sound frame of reference for those who are interested in space travel."

This is a fine purpose, but it proves too large for the limited scope of a 119-page book. The author does deal with some of the basic topics, such as space distances and destinations, rocket design and power, temperature control, power in space, and pressure in space. In very brief chapters, he does a good job of presenting some of the basic facts. Many of the concepts are illustrated with suggestions for experiments and demonstrations that the reader can carry out.

The brevity and simplicity of the book sometimes force the author to present generalizations and conclusions without enough background of supporting facts—the result is confusion rather than clarity. The principle of action and reaction, fundamental to any discussion of rockets, does not emerge clearly in the chapter devoted to it. The chapter, called "Powering the Ship," has only 12 pages, and most of these describe the setting up of demonstrations. The subjects of ram jets, turbo jets, turbo props, rockets, and partially related experiments are all included. It would have been better to stick to action and reaction and really put the idea across.

One of the clearest ways to demonstrate the reaction principle is with a toy balloon, yet only one paragraph at the end of this chapter mentions this standard device, and it is not illustrated.

Much of Branley's information seems to come from sources that are quite familiar to those who have read Ley, Clarke, the *Collier's* articles, and similar literature. Inclusion of these sources and an up-to-date reading list would have strengthened the book a great deal.

There are a few factual weaknesses. In Chapter 1 there is a worthwhile picture of distances in space and the time needed to traverse them. The author correctly selects the speed of release from the earth as the basis for the computations, but he neglects to point out the assumption of a continuous speed of 25,000 miles an hour, whereas current thinking asks only that it be reached to escape from the earth. During a journey to the moon, for instance, the motors are shut off and a condition of free flight sets in—the earth's gravitational effect slows it down continuously and the trip requires five days instead of 10 hours. High speed all the way is not only unnecessary but also undesirable.

It is well to correct here the impression

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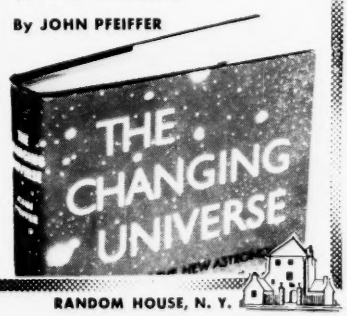

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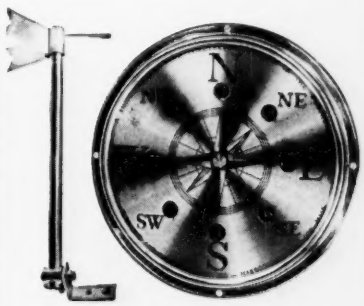

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on page 64 that a rocket takes off more easily from a space station "because of the small amount of gravitational pull." Actually, the earth's gravity diminishes relatively little at the short distance of the space station. What really helps is the station's orbital speed, of which the departing rocket ship partakes.

This educator approves so much of the purpose of the book that he wishes enough time and space had been given to achieve it more fully. What there is of the book is good, but it lacks both scope and depth.

JOHN STERNIG
Ass't. Supt. of Schools
Glencoe, Ill.

SUNSPOT AND GEOMAGNETIC-STORM DATA DERIVED FROM GREENWICH OBSERVATIONS 1874-1954

Royal Greenwich Observatory. Her Majesty's Stationery Office, London, 1955. 106 pages. £1 5s.

SIR J. Norman Lockyer in 1873 had to write a bitter footnote to a paragraph in praise of routine solar photographs taken at Kew and Ely observatories, adding, "Alas! this is no longer true! to the lasting disgrace of British Science the daily photographic record has ceased."

Since 1874, however, the Royal Greenwich Observatory has taken solar photographs daily, in co-operation with observatories at Kodaikanal, India, and Capetown, South Africa. Now, under the direction of the retiring Astronomer Royal, Sir Harold Spencer Jones, this volume has been prepared to summarize the solar data gathered at Greenwich in the succeeding 80 years.

The book contains mean daily data for each month and year concerning: a, projected areas of sunspots and faculae; b, these areas corrected for foreshortening effects; c, the distribution of spots in solar latitude for each synodic rotation of the sun (27.3 days); and d, geomagnetic data. Two tables list all sunspot groups larger than 0.0005 per cent and 0.0015 per cent of the solar hemisphere, respectively, with many notes. A list of all spotless days since 1874 is also given.

The great importance of sunspot observations was first realized when the relation between solar changes and certain terrestrial phenomena, such as magnetic storms, was discovered about the middle of the 19th century. This followed by only a few years Schwabe's discovery of the periodicity of sunspots.

In this book, the sunspot and faculae data are listed together with the monthly range in diurnal inequalities in magnetic declination: Zurich sunspot numbers are also given. A catalogue lists all great magnetic storms with notes on their special features, also all small storms since

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The publication of this memorable volume before the International Geophysical Year program gets into full swing is most opportune. The IGY period, July, 1957, through December, 1958, was selected to coincide with the maximum of sunspot activity, which seems almost certain to come in 1957.

There is no doubt that Sir Norman would now be proud if he could see the Greenwich sunspot and geomagnetic-storm data.

HARRY L. BONDY
Solar Division, AAVSO

THE POLAR AURORA

Carl Störmer. Oxford University Press, New York, 1955. 403 pages. $8.80.

BECAUSE of his age, and because he takes so much space for his own work, the author of this book is apologetic in the preface. But he is to be congratulated on writing a book after attaining the age of 75, and the volume summarizes his lifetime of research devoted to the aurora. And even though it represents the achievements of only one man and of those whom he has guided, the research described here is a sizable fraction of the total work on the subject.

In the first of two essentially equal parts, Professor Störmer presents observational data; this is excellent reference material on those aspects of the subject for which he had need and an immediate interest. Although the author is primarily a mathematician, he has exploited the hobby of photography to gain the knowledge necessary in his theoretical investigations.

The second part of the book, discussing the theory of aurora phenomena, would be a valuable addition by itself to any technical library. Here we find Professor Störmer's large number of studies of the trajectories of electric corpuscles in a magnetic field. Many of his earlier papers on the subject are very difficult to obtain. Without doubt, these treatises are a necessary basis for studies not only of the polar aurora but of cosmic rays and other associated topics.

There are excellent treatments of the forms of auroras, the measurements of their heights, and many descriptions of displays. Unusual phenomena are also considered. For example, two apparently trustworthy observations have been recorded of audible noise of auroras. However, the author indicates that the sounds heard may not have come directly from the auroras in question, since these were 90 to 100 kilometers overhead.

The Norwegian scientist suggests the possibility of electrical discharges in the neighborhood caused by the accumulation of electricity in the auroral region; he points out the need for new observations of electrical potential gradients. In this connection, we at College, Alaska, have been unable to establish any correlation of atmospheric electric potentials and auroral displays. This, therefore, leaves open the question of noise being propagated from those great heights of the atmosphere.

The book is well written; its format is good. Many illustrations are used, including some of Professor Störmer's excellent photographs of the northern lights. The arrangement of halftones, all placed at the end of the volume, is somewhat distracting, but each of them is given a number in sequence along with those of the diagrams that accompany the text.

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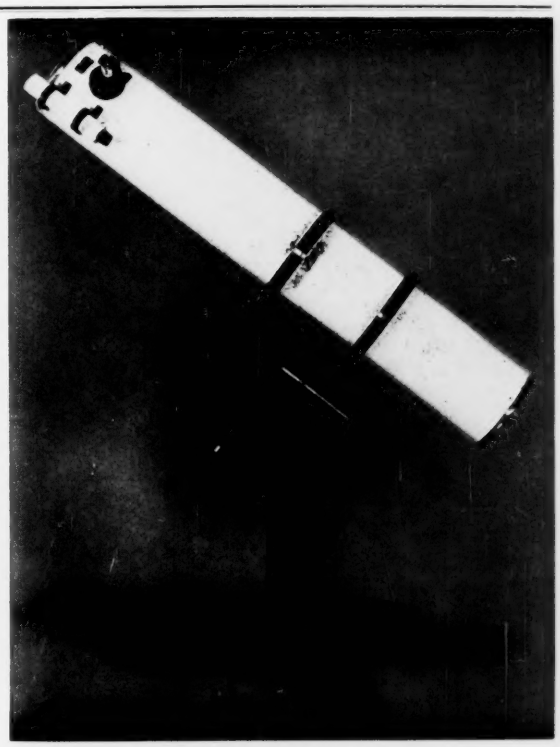

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THE ANALYTICAL THEORY OF HEAT, *Joseph Fourier*, 1955, *Dover*. 466 pages. $1.95, paper bound.

This reprint of Alexander Freeman's translation of 1878 makes again available Fourier's classical investigations of heat conduction, and the mathematical methods he invented for the purpose.

GEOMETRY OF FOUR DIMENSIONS, *Henry Parker Manning*, 1956, *Dover*. 348 pages. $3.95 cloth, $1.95 paper.

A standard treatise for students of mathematics, Manning's book is reprinted from the original 1914 edition.

BETWEEN THE PLANETS, *Fletcher Watson*, 1956, *Harvard University Press*. 188 pages and 67 plates. $5.00.

In this completely revised edition of one of the Harvard books on astronomy, which has as its subject comets, asteroids, meteors, and meteorites, important recent advances in our knowledge of the various kinds of interplanetary material are fully taken into account.

STONEHENGE, *R. J. C. Atkinson*, 1956, *Hamish Hamilton Ltd.*, 90 Great Russell St., London W. C. 1. 210 pages. 16s.

A British archeologist describes for general readers this remarkable prehistoric monument in southern England, discussing its history and its possible connection with astronomy.

ASTRONOMISCHER JAHRESBERICHT, Vol. 53, 1955, *Astronomischen Rechen-Institut*, Grabengasse 14, Heidelberg, Germany. 468 pages. DM 40, paper bound.

This current volume of a standard reference work is a comprehensive listing of the astronomical literature published during 1953. The titles are arranged by subject, and all important article references are accompanied by a short abstract in German.

THE MEANING OF RELATIVITY, *Albert Einstein*, 1956, *Princeton University Press*. 169 pages. $3.75.

The lectures on relativity which Einstein gave in 1921 at Princeton here appear in a fifth edition, with much additional material, including a revised version of his generalized theory of gravitation.

EXPANDING UNIVERSES, *E. Schrödinger*, 1956, *Cambridge University Press*. 93 pages. $3.50.

In the summer of 1954, one of the world's leading cosmogonists, Erwin Schrödinger, senior professor in the Institute for Advanced Study at Dublin, delivered a series of lectures to an advanced seminar group. This book is based on this series, in which the "empty universe" of de Sitter is dealt with at great length. The treatment is technical, requiring a working knowledge of relativity.

ELECTRONICS, *A. W. Keen*, 1956, *Philosophical Library*. 256 pages. $7.50.

Vacuum tubes, transistors, and other electronic devices are explained in this book, together with practical applications of electronics such as radio, radar, television, and computers. Non-mathematical in character, the book is intended as a survey that can be understood by persons knowing elementary electricity and magnetism.

THE WORLD OF ATOMS, *J. J. G. McCue*, 1956, *Ronald Press*. 659 pages. $6.50.

This college textbook for introductory physical science courses gives a broad background of general physics and chemistry, emphasizing atomic and nuclear physics.

ROCKETS AND GUIDED MISSILES, *John Humphries*, 1956, *Macmillan*. 229 pages. $6.00.

A British expert gives an over-all picture of rocket motors and their applications, intended especially for engineers engaged in other fields. There is an 18-page bibliography of the subject.

ATLAS DU CIEL, *Vincent de Callatay*, 1955, *Editions De Visscher*, 17 Rue du Grand Cerf, Brussels, Belgium. 157 pages. Price not given.

The 36 large white-on-black maps of this lavish atlas show both northern and southern stars down to the 5th magnitude. They are accompanied by labeled finder charts, descriptions of the constellations, and lists of bright stars and interesting objects for amateur telescopes. The page size is 9¼ by 12½ inches.

The text is in French, and includes a considerable amount of information on astronomy as a whole, interspersed with the descriptions of the constellations and the observing lists. At the end of the volume are a dozen astronomical photographs.

GEOMETRICAL OPTICS, *L. C. Martin*, 1956, *Philosophical Library*. 215 pages. $7.50.

This is an English textbook for university courses. The chapter headings are: The Laws of Geometrical Optics; The Paraxial Theory of Optical Systems; Optical Instruments; The Relation between Geometrical and Physical Optics; The Observation and Recording of Images; Photometry; and the Aberrations of Optical Images.

There are seven Appendixes: Laws of Refraction; Vector Forms; Depth of Focus; Physical Discussion; Depth of Focus of a Lens in the Object Space; Refractive Index Data; Dispersion Formulae; The Optics of Non-homogeneous Media; Refraction of Rays Enclosing an Element of Solid Angle. There are answers to the problems that conclude each chapter, and an index.

THE GOLDEN BOOK OF SCIENCE, *Bertha Morris Parker* and *Harry McNaught*, 1956, *Simon and Schuster*. 97 pages. $3.95.

Another in the lavishly illustrated Golden Book series for children, this book deals with science in general, including some discussion of astronomy.

Astronomy Books

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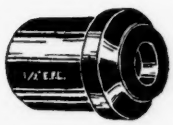

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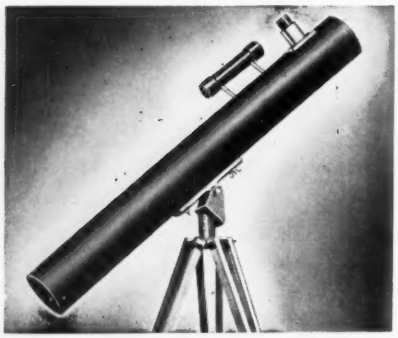

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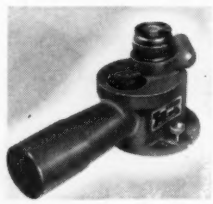

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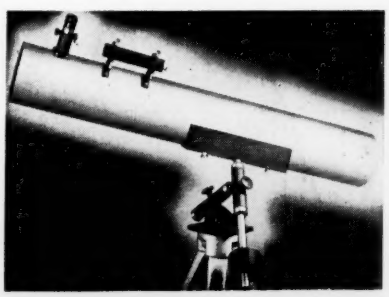

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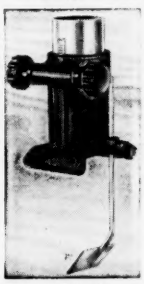

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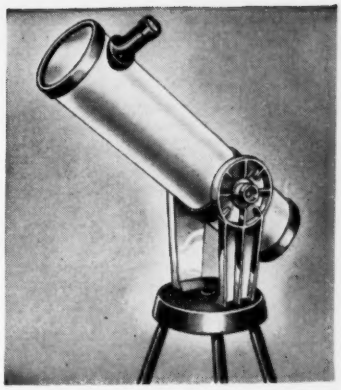

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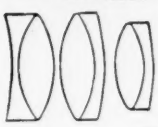

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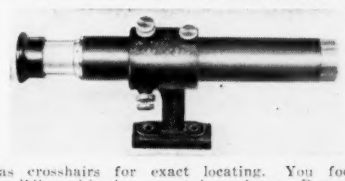

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A Closed Tube, Low-Diffraction, Portable Reflector — I

ENTHUSIASTIC observers, especially those who can spend only occasional nocturnal periods at the eyepiece, frequently find their eagerness for observing with reflectors thwarted by one or several conditions: The reflecting surfaces are dusty or corroded. Tube currents upset the mirror correction and cause image unsteadiness. Dewing of the optical surfaces occurs. Excessive diffraction spoils definition.[1] The system has become misaligned.

Late in 1954 I built a portable f/15 reflector of 7.6-inch aperture that was designed to eliminate these irritations (Fig. 1). More than a year of use has shown the instrument to perform as expected, so a description of its mechanical and optical construction may be useful to others.

The first two difficulties are avoided by the use of a closed metal tube, containing an atmosphere which is dry, free from corrosive gases, and at the same pressure as the surrounding air. Dewing of the air-exposed surface is prevented by an electrically heated dewcap and that of the inner surfaces by the dry air in the tube.

Spider diffraction is eliminated by mounting the diagonal on a plane-parallel glass plate, and diffraction due to the central obstruction is made insignificant by means of Lyle T. Johnson's ingenious modification of the Gregorian optical system,[2] as shown in Fig. 2. Stability of alignment is assured by the strain-free mounting of all components in nonadjustable, rigid cells of low heat conductivity.

The finder is a war-surplus, 8-power elbow telescope, with a field of eight degrees. Its reticle is illuminated by a 3-volt wheat-grain bulb and a 1½-volt flashlight cell, all integrally mounted on the dewcap extension of the main tube.

The heater on the dewcap is wound with No. 24 copper wire (8 ohms resistance) and insulated with 1/16" cork and aluminum foil, which can be seen in Fig. 3. The automobile battery, seen on the

[1] *Amateur Telescope Making—Book Three*, pages 469-478.

[2] *Scientific American*, September, 1949, pages 60-63.

Fig. 1. The Selby reflector ready for use, with portable power supply.

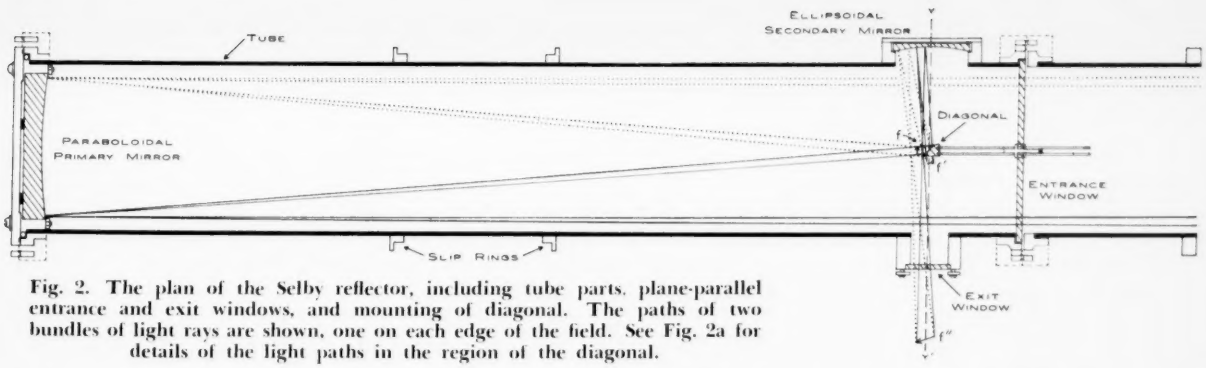

Fig. 2. The plan of the Selby reflector, including tube parts, plane-parallel entrance and exit windows, and mounting of diagonal. The paths of two bundles of light rays are shown, one on each edge of the field. See Fig. 2a for details of the light paths in the region of the diagonal.

floor in Fig. 1, has taps to provide from 2.1 to 12.6 volts at 2.1-volt intervals. This gives heating effects from 1.9 to 69 B.T.U. per hour. The current drain varies from 0.26 to 1.6 amperes.

The lowest voltage is sufficient to cope with all but heavy dew and causes no detectable image deterioration. At 6.3 volts, there is a slight image effect and water can be running from the tube proper while the plane-parallel entrance plate remains clear. The top heat is used for warming up only.

Above the tube in Fig. 3 can be seen the accessory mount, which consists of an aluminum saddle holding the $2\frac{1}{2}$″ by $\frac{1}{4}$″ plane-parallel exit window, surmounted by a Masonite slide accommodating five gelatin filters. The focusing mount, into which the camera holder is inserted, has a 1.65″ by 10 interrupted thread for rapid exchange of parfocal and other oculars, plateholder, and the camera. This camera has a 10x amplifying lens attached. The mounting turns about the pivot in the aluminum saddle, intersecting the focus, to compensate for the tilting of the image surface that is inherent in the telescope design, as shown in Fig. 2.

The rotatable telescope tube is of rolled and welded 3003 aluminum $\frac{1}{8}$″ thick and 9.2″ inside diameter. The flange rings rolled and welded to the tube are $\frac{3}{4}$″ thick, 12″ outside diameter, and the center flanges were turned to form step bearings to which the saddle and $\frac{1}{2}$″ by $\frac{1}{8}$″ brass straps are fitted. The carrying handle (Fig. 1) is linked to the straps.

Beneath the lower part of the telescope tube in Fig. 1 may be seen the cylinder holding the absorbing material that keeps the inside air clean and dry. This lucite cylinder is $1\frac{1}{4}$″ in diameter and 18″ long, connected to the main tube by the hose and pipe fitting at its upper end. It is packed with indicating activated alumina. When the cobalt chloride indicator shows the desiccant to be exhausted, it is regenerated at 350° Fahrenheit. Thus, the tube interior is kept free from moisture, acid gases, and dust.

W. Everest's town-pump type of equatorial head[3] was modified to provide quick alignment on the celestial pole by

[3] *Amateur Telescope Making—Book Two*, pages 513-514.

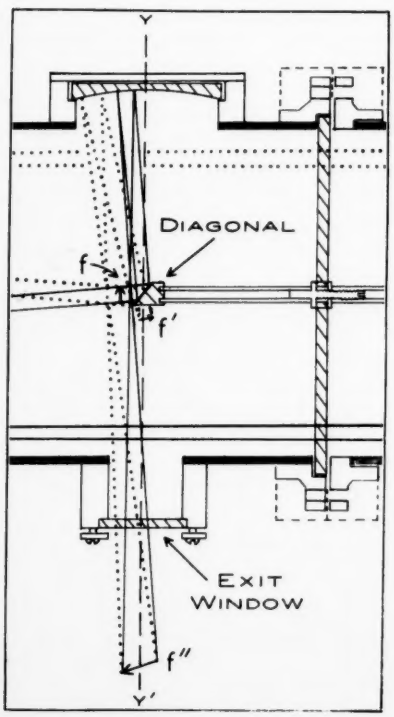

Fig. 2a. Part of Fig. 2 enlarged. Here the prime focus is at f, just in front of a very small diagonal, which reflects the light to the ellipsoidal secondary, one focus of which is at f′, the other at f″, where the image is formed in a position inclined to the side of the main tube.

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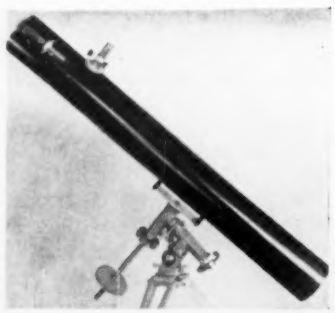

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means of an objective lens of 12-inch focal length mounted at the north end of the polar axis. The south end has a removable angle eyepiece (Fig. 4) and a reticle with a circle equivalent to the diurnal path of Polaris and with radial hour lines. The image of Polaris is brought onto this circle at the proper hour-angle position (as predicted in the *American Ephemeris*) by turning the mounting head on the tripod and by using the tripod leg-spread adjustments. The declination axis has 1¼″ transverse holes to provide for this polar view; one of these holes is visible in Fig. 5. For approximate alignment when Polaris is not visible, two levels and a compass needle are provided.

The north end of the polar axle is an automobile flywheel, turned smooth to roll on double-row ball bearings. Another bearing rolls on the inside of the flywheel, allowing the drive to be carried by grasping the top of the wheel. The south end of the axle runs on single-row ball bearings. The whole mounting assembly rests on a large square plate, which can be rotated in azimuth on the tripod head.

The right-ascension worm wheel (Fig. 4) is a narrow ring cut from a stock

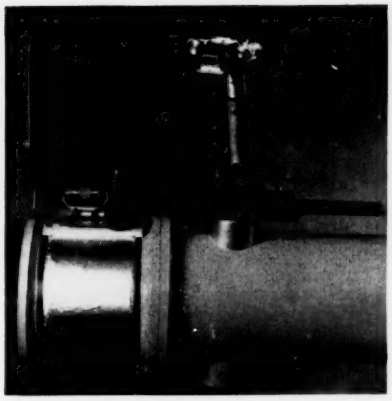

Fig. 3. The upper-tube assembly, including dewcap and camera holder.

spoked gear. It rides in a channel turned in pipe flanges, and the tension of the flanges on the gear is adjustable for drag. The worm is turned by a 900-to-1 stock reducer served by a jack shaft with belts and pulleys. The motor is war-surplus, 27-volt d.c. with a permanent magnet field; it is mounted in sponge rubber and measures only 1″ by 1″ by 2¼″. It operates from a pack of 18 size-D flashlight cells, with its speed controlled by a 200-

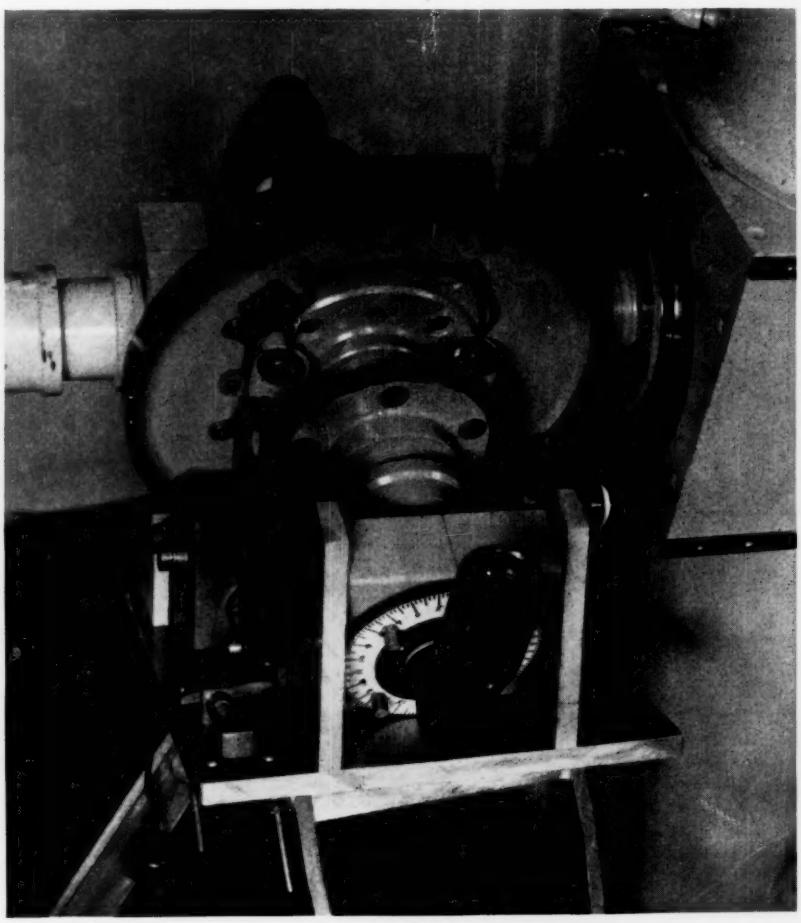

Fig. 4. The south side of the equatorial head.

ohm 10-turn potentiometer used as a rheostat. During use, the current is 65 to 80 milliamperes. The pack has a service life of 10 to 25 hours.

The pulleys were trued on their shafts while running in their own bearings, to avoid cyclic speed errors, and friction was brought to a minimum by precise fitting of bearings and the use of thin seamless rubber rings for belts. Motor vibration was minimized by floating on mercury and observing ripples at operating speed. The pulley was oriented on the shaft at the position of least vibration, after which the weight of the set screw was varied to gain maximum smoothness.

The declination axle was turned to 2.28″ from extra-strong pipe and mounted in blocks of 1⅛″ hard Masonite, graphite treated, seen in Fig. 5. The tension is regulated at the lower block, which is spring-separated. There is no slow motion in declination.

The hour circle, at the south end of the polar axis (Fig. 4), was hand-drawn on Bristol board, lacquered and mounted in slip rings. It is graduated to 10 minutes of time.

The declination circle is an 8″ transparent protractor, graduated to 30 minutes of arc and underlaid with a white card carrying numbers from 0° to 90° and back again. Reading microscopes made from 8-power elbow telescopes are used 180° apart to eliminate eccentricity error; they may be seen mounted on the upper flange of the polar-axis assembly. The declination circle and the reading reticles are illuminated by penlite bulbs, the batteries for which are located on the underside of the polar-axis flange (Fig. 4). Calibration of the declination circle showed the maximum error for the mean of a pair of readings to be eight minutes of arc.

The tripod is made of aluminum throughout. The legs are of 1″ by ⅜″ stock with spreading adjustment by wing nuts. The entire instrument can be transported by car with ease and assembled in 20 minutes, including alignment with the earth's axis. Taking apart and reloading consume about 10 minutes. The tube weight is 67 pounds, declination axle 36, drive 40, tripod 10, and box of accessories 25 pounds.

For axial definition, the Johnsonian system is equal to any. Off-axis definition on a line at right angles to the tube is superior to a comparable Newtonian or Cassegrainian and equal to a standard Gregorian, with its low coma, astigmatism,

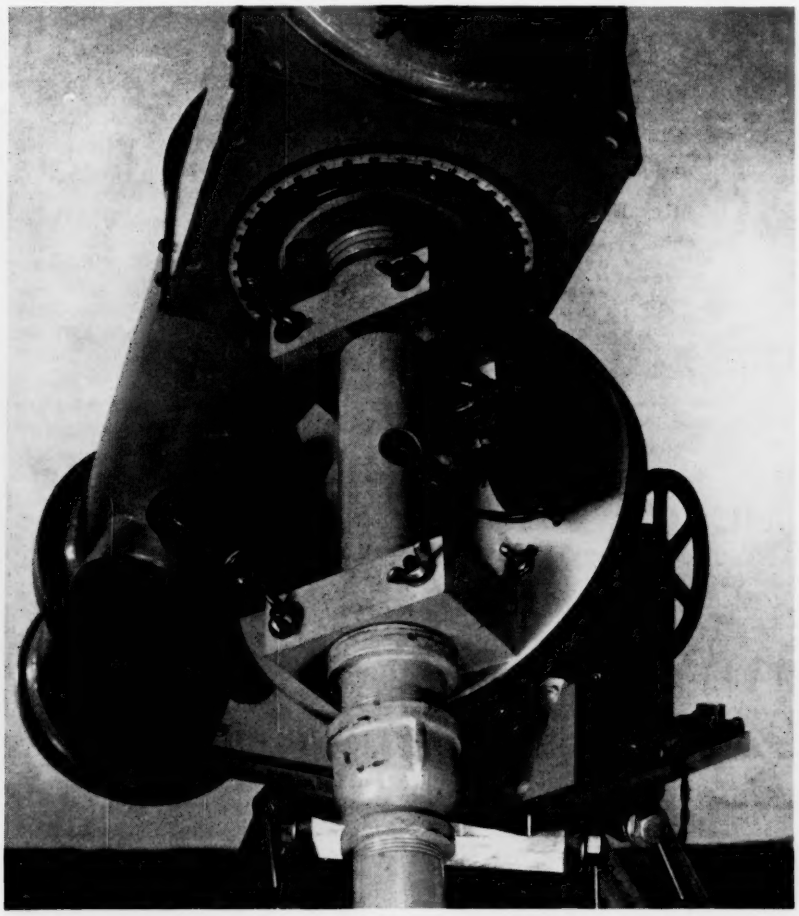

Fig. 5. The north side of the equatorial head.

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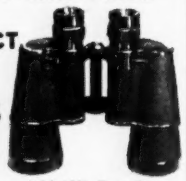

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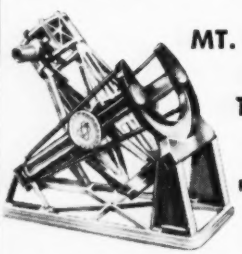

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and other aberrations. On a line normal to this and in a plane perpendicular to the axial cone from the ellipsoidal secondary mirror, the imagery is poor. It is in this plane that the maximum uniformity of field illumination is found, however.

As can be seen in Fig. 2, the unavoidable tilting of the diagonal causes the virtual primary image f′ to be presented to the ellipsoid at an angle not perpendicular to its axis. Since the secondary magnifies both longitudinally as well as laterally, the final image, f″, is canted even more with respect to the plane of most uniform brightness. By arranging the focusing mount so it pivots around the transverse axis passing through the secondary focus, either best illumination or best over-all definition can be chosen.

It is my practice to take photographs at the focus in the plane of maximum resolution, to observe at the position of most uniform brightness, and to photograph with auxiliary systems at intermediate angles. Although one extremity of the primary image is too close to and the other too far from the minor conjugate focus of the ellipsoidal mirror for optimum correction, the edge definition, when the best compensating tilt is employed, is equal to that given by a paraboloid-hyperboloid Cassegrainian, though slightly inferior to that of a normal Gregorian.

This modified Johnsonian telescope has proved completely satisfactory and it is a delight to use. On the optical bench the diameter of the axial Airy disk has been found to vary from 17.5 to 19 microns over the last year. Theory gives 19.6 microns. Apparently, travel of over a thousand miles has not affected the initial alignment.

Also on the optical bench, the instrument shows two equally bright sources as an elongated single image when their centers are 0.4 second of arc apart, and it separates them at 0.65 second. Dawes' limit for this aperture is 0.60 second. Seeing has been no better than 6 for any extended period when I have observed during the past year, so I have not been able to give the system a rigorous check. I have, however, resolved the following doubles:

Star	*Separation* (seconds)	*Magnitudes*
Zeta Orionis	2.5	2 and 4
Castor	2.2	2 and 3
Delta Cygni	2.1	3 and 6
Zeta Herculis	1.6	3 and 6
Mu Cygni	1.5	5 and 6
10 Ursae Majoris	0.65	4 and 6

In the next part of this article, I shall describe the construction of the optical elements, as well as collimation and alignment.

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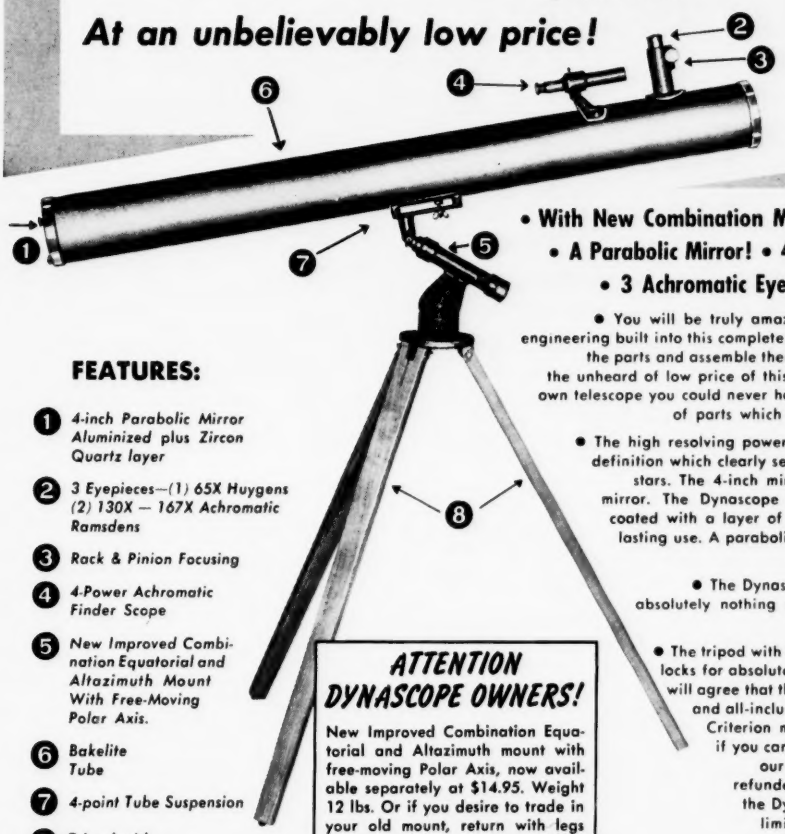

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2. *3 Eyepieces—(1) 65X Huygens (2) 130X — 167X Achromatic Ramsdens*
3. *Rack & Pinion Focusing*
4. *4-Power Achromatic Finder Scope*
5. *New Improved Combination Equatorial and Altazimuth Mount With Free-Moving Polar Axis.*
6. *Bakelite Tube*
7. *4-point Tube Suspension*
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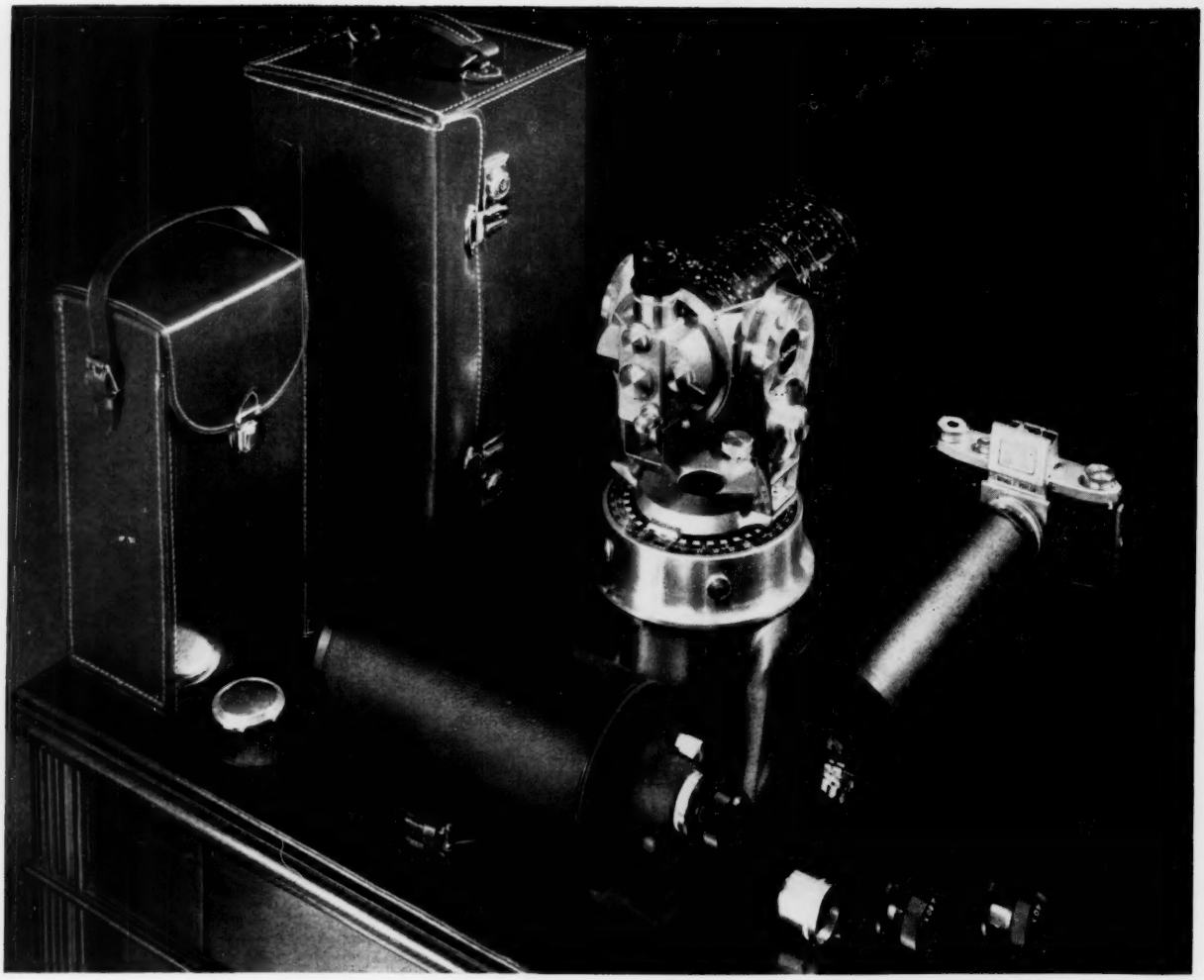

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The square nameplate on the Field Model reads "Questar Catadioptric Photo-Visual Telescope F:12.1 AP 89 mm. FL 1077 mm." So sharp a 42.4" lens is in itself a challenge to the 35-mm. photographer. How much of what Questar shows so clearly will he be able to capture on his negative? Achieving theoretical perfection of image for its 3½" aperture, this instrument furthermore brings all colors, including the infrared, to the same focal point.

For the amateur, this 31-ounce telescope represents the utmost in convenience and versatility. He may mount it to suit his fancy for the host of astronomical uses at which it excels. With the amateur's needs in mind we have bored the bracket casting cylindrically to take any standard 1¼" diameter ocular or accessory. This means that your own battery of favorite eyepieces, Barlows, prisms and auxiliary equipment may be used, at any power you choose. And a large nylon tangent screw may be tightened with a coin to clamp each accessory firmly without danger of surface scratches.

The bracket itself is of high-strength heat-treated aluminum alloy, black anodized after machining. Its 2" x 2" base is tapped for both foreign and domestic tripod screws.

The barrel of the Field Model Questar is covered in genuine Morocco leather at the studios of Albert Oldach & Son of Philadelphia, binders of fine books since 1875. The handsome velvet-lined leather case is included in the purchase price and is handmade in England, of the same materials its makers use for the case of the De Luxe Questar. An extension strap provides for shoulder carrying when desired. Instrument and case together weigh less than 3 pounds.

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Questar Field Model in case, $195, your check for $100 will reserve an instrument; Questar 40x Eyepiece, $20; Questar Wide-Field Erfle 80x Eyepiece, $25; Questar Eyepiece Adapter Tube, $6.00 (only one required); Questar Sun Filter, $25; De Luxe Questar with all accessories, $995, reservation $300. All are shipped insured and prepaid in the continental United States.

QUESTAR CORPORATION

NEW HOPE, PENNSYLVANIA

OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Determining the Field of an Eyepiece

EVERY observer finds it useful to know the angular width of the field of view for each of the eyepieces of his telescope. For a low-power eyepiece, a simple but rough method is to estimate the size of the field in terms of the apparent diameter of the sun or moon, both of which average about 30 minutes of arc.

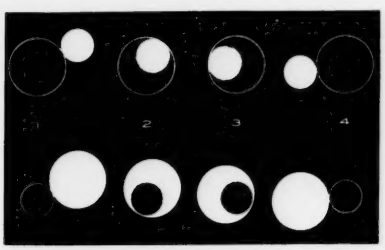
A better procedure, widely used, is to time the interval for a star to drift centrally across the field, when the telescope is stationary. If the interval is **t** seconds, and **D** the field diameter in minutes of arc, then

$$\mathbf{D} = \tfrac{1}{4}\mathbf{t} \cos \mathbf{dec}.$$

If the star is within a few degrees of the celestial equator, as in Orion's Belt, the factor cos **dec** can be considered equal to one. This second method is only approximate, as the star may not follow a path that is exactly central across the field.

If your telescope is equipped for *safe* solar observing (with a very dense filter and reduced aperture, for example), more accuracy than with either the above ways can be obtained by letting the sun drift across the field. Time each of the four instants when the sun's disk is externally tangent and internally tangent to the field of view.

Let **T** be the interval between the moments of external tangency, and **T′** the interval for internal tangency, both expressed in seconds of time. Call the sun's



The moments to be timed are illustrated here, the upper row for a field of view larger than the sun (white), the lower for a small field. The sun's motion is leftward: 1, tangent to the field; 2, internally tangent; 3, starting to leave the field; 4, externally tangent.

semidiameter **S**, expressed in minutes of arc, and its declination **dec**. Then the formula for the field width in minutes of arc is

$$\mathbf{D} = \frac{(\mathbf{T} + \mathbf{T}')(\mathbf{T} - \mathbf{T}') \cos^2 \mathbf{dec}}{128\,\mathbf{S}}.$$

To illustrate this method, on March 10, 1956, I used a 3-inch telescope bearing a 60x eyepiece and a dark solar filter. The telescope was clamped in one position, and care was taken not to touch it during the observation. The sun began to enter the field at 1:54:11 Eastern standard time; it was entirely within the field at 1:56:50; it began to leave the field at 1:57:27; it was entirely outside at 1:59:38.

Subtracting the first time from the fourth gives $\mathbf{T} = 297$ seconds, and the second from the third gives $\mathbf{T}' = 37$ seconds. For this observation the sun's semidiameter, **S**, was 16′.13, according to the *American Ephemeris*, and its declination was −3° 52′.2. When these numbers are substituted in the formula, the diameter of the field comes out as 41′.9.

In all, six such determinations were made, averaging 41′.9, and with an extreme range of only 0′.4. This procedure is thus relatively precise. Note that the sun need not pass centrally through the field of view.

The formula is derived in W. Chauvenet's *Spherical and Practical Astronomy*, Vol. 2, pages 445-446. Strictly speaking, the intervals **T** and **T′** should be expressed in apparent time, but the use of ordinary or mean time instead will never introduce an error of more than about 0.2 per cent.

J. A.

VARIABLE STAR MAXIMA

June 1, T Centauri, 133633, 6.1; 2, RR Scorpii, 165030, 6.0; 3, RS Cygni, 200938, 7.4; 15, T Cassiopeiae, 001755, 7.8; 15, RU Sagittarii, 195142, 7.2; 16, S Coronae Borealis, 151731, 7.5; 17, R Leporis, 045514, 6.7; 21, R Virginis, 123307, 6.9; 22, W Andromedae, 021143, 7.5; 25, R Normae, 152849, 7.2; 26, RT Sagittarii, 201139, 7.9; 27, R Ursae Majoris, 103769, 7.6; 28, RT Cygni, 194048, 7.4.

July 5, R Aquilae, 190108, 6.3; 6, T Ursae Majoris, 123160, 7.9.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

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SUNSPOT NUMBERS

March 1, 127, 152; **2**, 113, 120; **3**, 104, 115; **4**, 98, 90; **5**, 86, 112; **6**, 94, 110; **7**, 102, 107; **8**, 103, 104; **9**, 83, 102; **10**, 80, 97; **11**, 77, 84; **12**, 77, 80; **13**, 85, 97; **14**, 103, 122; **15**, 111, 144; **16**, 123, 120; **17**, 102, 138; **18**, 116, 122; **19**, 118, 120; **20**, 112, 118; **21**, 114, 115; **22**, 146, 103; **23**, 123, 120; **24**, 134, 136; **25**, 110, 138; **26**, 123, 140; **27**, 103, 106; **28**, 105, 115; **29**, 104, 122; **30**, 118, 113; **31**, 88, 118. Means for March: 105.9 American, 115.5 Zurich.

Above are given the date, the American number, then the Zurich number. These are observed mean relative sunspot numbers, the American computed by D. W. Rosebrugh from AAVSO Solar Division observations, the Zurich numbers from Zurich Observatory and its stations in Locarno and Arosa.

Zurich provisional sunspot numbers are transmitted by the Swiss Broadcasting Corporation by short wave on the 4th and 5th of the following month. Listeners in North America can hear these reports on the 5th of each month at 01:35 UT on wave lengths of 48.66, 31.46, and 25.28 meters, and at 04:20 UT on the same wave lengths. Reports beamed to South America at 23:30 UT on the 4th are on 31.46, 25.28, and 19.60 meters; and at 03:45 UT on the 5th on 31.46 and 25.28 meters. This revised schedule will be used until and including October, 1956.

MOON PHASES AND DISTANCE

Last quarter	June	1, 19:13
New moon	June	8, 21:29
First quarter	June	15, 11:56
Full moon	June	23, 6:13
Last quarter	July	1, 8:10

	June	Distance	Diameter
Perigee	10, 3^h	223,500 mi.	33′ 13″
Apogee	25, 8^h	252,300 mi.	29′ 26″
	July		
Perigee	8, 11^h	222,100 mi.	33′ 26″

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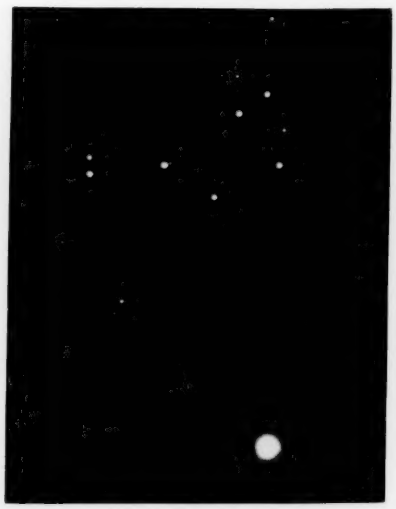
VENUS AND THE PLEIADES



The brilliant planet Venus was photographed on April 2, 1956, as it was passing close to the Pleiades, by Frank J. Achfeld, in Northumberland, England. He used an f/5.8 camera of 19½ inches focal length, with a 10-minute exposure on an Ilford Astra VII plate. Only two nights earlier, the discovery of a 5th-magnitude comet was reported by Tcherepahtuk, in Russia, who gave a position very close to Alcyone, the brightest of the Pleiades. However, no one else appears to have seen it, and all the images in the reproduction can be identified with previously known objects. Venus' image is overexposed.

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UNIVERSAL TIME (UT)

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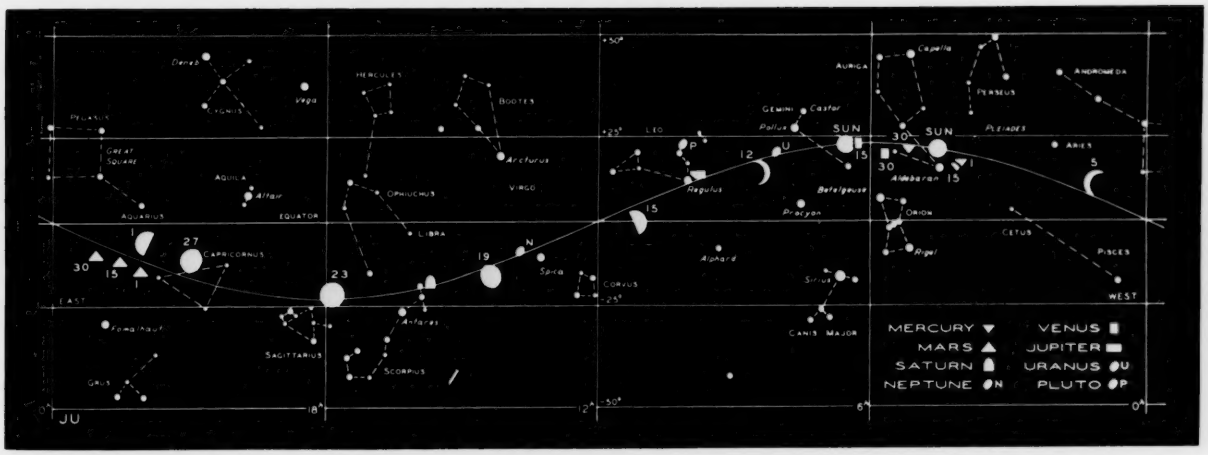


THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

The sun will be totally eclipsed on June 8th, with the path of totality in the South Pacific Ocean. Maximum duration of totality will be $4\frac{3}{4}$ minutes. Only observers on New Zealand and the South Sea islands may view the partial eclipse.

Mercury appears as a morning star, attaining greatest elongation on June 20th, 22° 46′ west of the sun. The planet then rises about one hour before the sun, appearing at magnitude +0.7. On June 23rd, Mercury passes $2\frac{1}{2}$° north of Aldebaran in Taurus, the planet being half a magnitude brighter than the star.

Venus begins the month in the evening sky, setting two hours after the sun but moving toward it rapidly. Use a pair of good binoculars or a telescope to observe the large, slender crescent, 47″.7 in diameter, 13 per cent illuminated. The planet will be at magnitude −4.0. By the middle of the month, the crescent will grow to 56″, with only 2.4 per cent of Venus' disk illuminated. It will be difficult to observe, as the planet then sets only three quarters of an hour after the sun. On June 22nd, Venus passes between us and the sun, reaching inferior conjunction, and enters the morning sky, where the planet will become visible early in July.

The earth arrives at heliocentric longitude 270° on June 21st at 10:24 UT, when summer commences in the Northern Hemisphere and winter in the Southern.

Mars continues its eastward motion through Aquarius, rising at midnight in early June. Mars has brightened considerably, and is of magnitude −0.6 in midmonth. The planet's disk has a diameter of 13″ on June 15th.

Jupiter may be observed only during evening hours, in the western sky. It is approaching Regulus again, and will pass 35′ north of the star on July 2nd.

Saturn passed opposition to the sun last month, and therefore can be observed most of the night. Located in eastern Libra, the planet is in retrograde motion. Its magnitude in mid-June is +0.4, and the ring system appears inclined 23°.8 to our line of sight, with the northern face in view.

Uranus, about 7° west of the Praesepe cluster in Cancer, sets soon after the sun, and may be observed only in early June.

Neptune sets about midnight; it is in retrograde motion in eastern Virgo, as shown by the chart on page 191 of the February issue. E. O.

MINIMA OF ALGOL

June 1, 10:44; 4, 7:32; 7, 4:21; 10, 1:10; 12, 21:59; 15, 18:48; 18, 15:37; 21, 12:25; 24, 9:14; 27, 6:03; 30, 2:51. July 2, 23:40; 5, 20:29; 8, 17:17; 11, 14:06.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

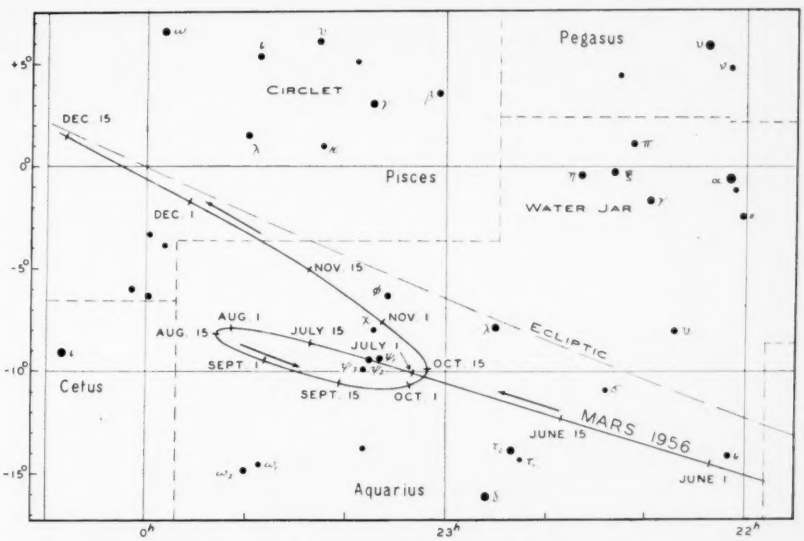
Prokne, 194, 9.4. June 6, 18:45.5 +7-17; 16, 18:39.6 +7-40; 26, 18:32.0 +7-27. July 6, 18:23.9 +6-34; 16, 18:16.3 +5-01; 26, 18:10.5 +2-58.

Juno, 3, 9.5. June 6, 19:20.0 −4-51; 16, 19:13.9 −4-38; 26, 19:06.3 −4-39. July 6, 18:57.6 −4-54; 16, 18:48.8 −5-24; 26, 18:40.7 −6-06.

Alexandra, 54, 9.6. June 16, 19:49.8 −32-45; 26, 19:42.3 −32-25. July 6, 19:32.4 −31-53; 16, 19:21.7 −31-05; 26, 19:11.7 −30-03. August 5, 19:03.9 −28-49.

Hygiea, 10, 9.1. June 26, 19:59.7 −20-02. July 6, 19:52.2 −20-09; 16, 19:43.9 −20-17; 26, 19:35.6 −20-25. August 5, 19:28.2 −20-31; 15, 19:22.5 −20-34.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.



The path of Mars among the stars for the remainder of this year. Until August the red planet moves eastward, and then begins its westward (retrograde) travel, resuming direct motion in October. When Mars is at opposition to the sun on September 11th, it will be a little over 35 million miles distant from us.

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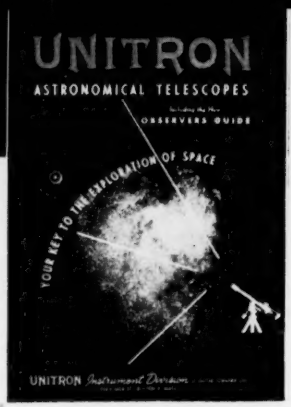

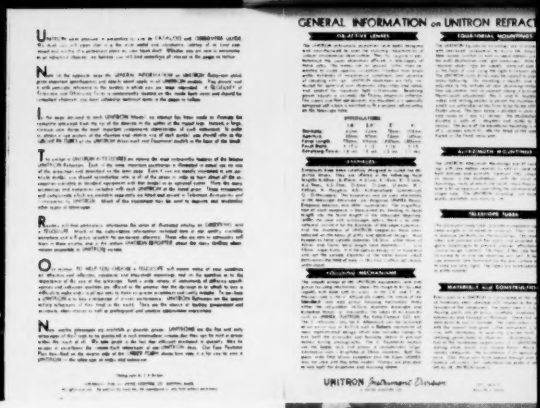

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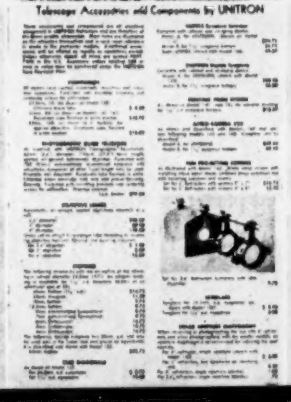

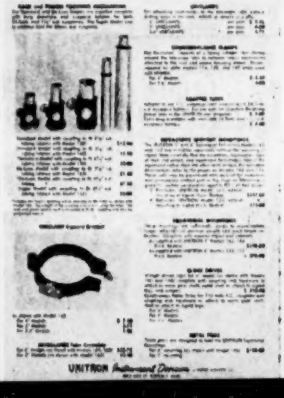

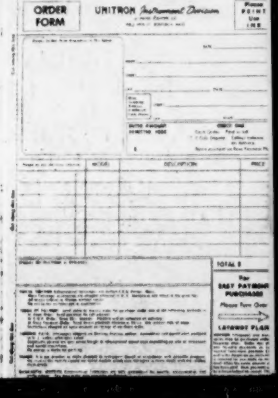

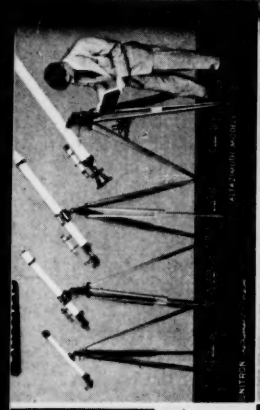

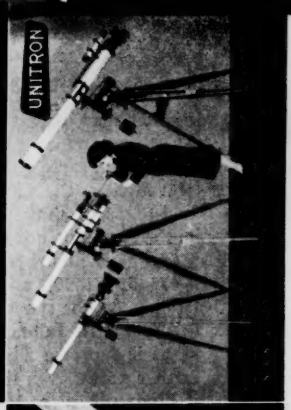

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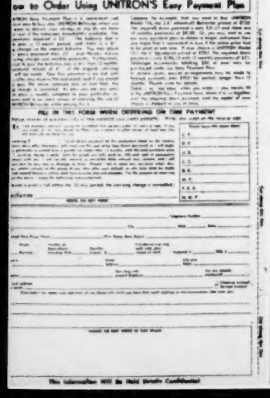

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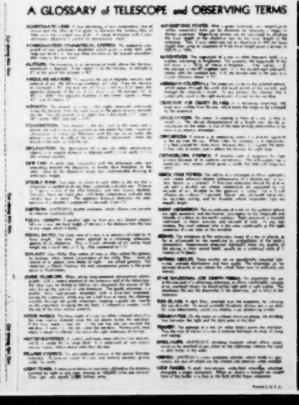
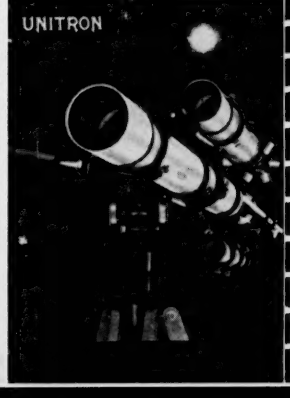


A GLOSSARY of TELESCOPE and OBSERVING TERMS



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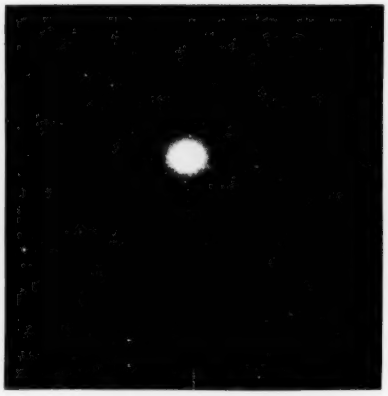
DEEP-SKY WONDERS

IN THEORY, an observer in the Northern Hemisphere can see into southern declinations as far as his colatitude (90° minus latitude). Ordinarily horizon mists, smoke, and dust take a good 10 or 15 degrees off this figure. But in some fortunate regions, and at times almost everywhere, there come nights when extinction is small and stars can be seen down to the horizon. Then the great cluster Omega Centauri is visible to amateurs living as far north as New York City, Pittsburgh, Cincinnati, and San Francisco.

It can also be seen in the clean skies of the Great Plains from Manhattan, Kans. A few nights ago a visitor from New York said he had never seen it, and, trusting to theory and my growing faith in Kansas skies, I offered to show him this cluster. And there it was in the binoculars, its lower edge just tangent to the top of the Flint Hills. In the 6 x 30's its immense size was obvious, and while it had lost about three magnitudes by extinction, the brighter stars came through clearly, making it look more like a bright galactic cluster than the globular it really is. The next night at the same time a 6-inch rich-field telescope showed clearly the blaze of its thousands of unresolved stars.



John Herschel, viewing Omega Centauri from South Africa on March 2, 1837, called it a "most glorious sight." Its central blaze filled the field of his 18¼-inch reflector, at 180x. The scale of this Harvard Observatory photograph, reduced from an ADH telescope negative, is 1.4 degrees per inch.

Omega Centauri is located at $13^h\ 23^m.8$, $-47°\ 03'$ (1950), and is marked by the letter ω on the star chart on page 382 of this issue. Its full-moon diameter would make it supreme among clusters were it farther north; even skimming the horizon it obviously surpassed M13 in Hercules and M5 in Serpens, though both were riding high in a black-velvet sky.

If haze dims Omega beyond your reach, however, try a few degrees farther north for NGC 5128 at $13^h\ 22^m.4$, $-42°\ 45'$. This 7.2-magnitude galaxy, 10′ by 8′ in angular size, has its center cut out by a huge swath of dark absorption. It has no close counterpart in the sky, and while the Shapley-Ames catalogue includes it as a galaxy, there has been much debate about its true nature.

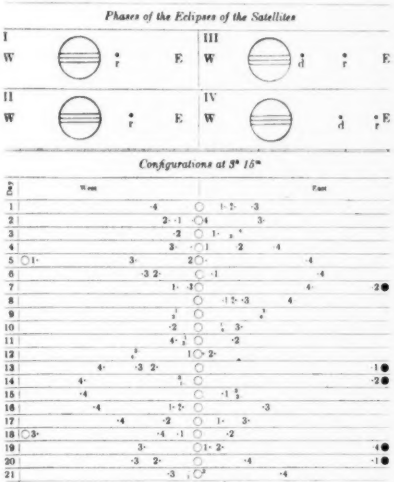
If both of these fail, one can always climb higher to M83 in Hydra, at $13^h\ 34^m.3$, $-29°\ 37'$. It is nearly as large as NGC 5128 and about as bright. This time there is no argument about its nature, for photographs show clearly that it is a type Sc galaxy—a well opened spiral.

WALTER SCOTT HOUSTON
Rt. 3, Manhattan, Kans.

JUPITER'S SATELLITES

The configurations of Jupiter's four bright moons are shown below, as seen in an astronomical or inverting telescope, with north at the bottom and east at the right. In the upper part, *d* is the point of disappearance of the satellite in Jupiter's shadow; *r* is the point of reappearance.

In the lower section, the moons have the positions shown for the Universal time given. The motion of each satellite is from the dot toward the number designating it. Transits over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the *American Ephemeris and Nautical Almanac*.



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ASTRONOMICAL stamp album. Valued at over $100.00. Make offer. Write Box A, *Sky and Telescope*, Harvard Observatory, Cambridge 38, Mass.

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INTERESTED in astronomy as a career? *Vocational and Professional Monographs: Astronomy* by Freeman D. Miller describes personal qualifications, scholastic training, and job opportunities. $1.00 postpaid. Write Box B, *Sky and Telescope*, Harvard Observatory, Cambridge 38, Mass.

BRAYTON Optical Exchange now offers 4" equatorial refractor, $495.00, and 4" kit, $395.00. Details, photos on request. Identical with 8" refractor advertised in April issue, *Sky and Telescope*. Star diagonals, $8.50; with Barlow attachment, $17.50. 296-A Brown's Valley Rd., Watsonville, Calif.

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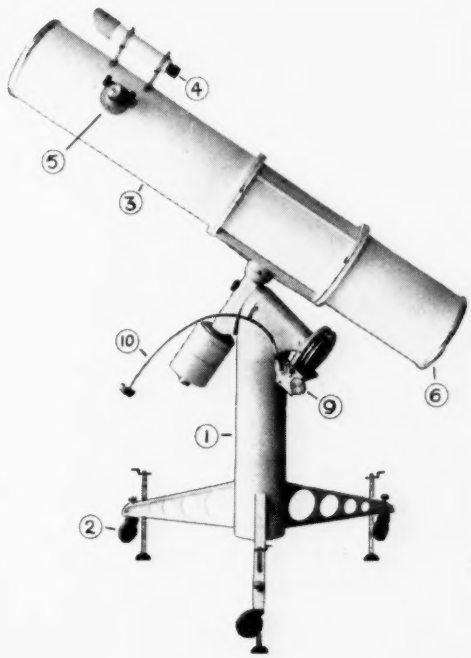

All models are the pinnacle of precision craftsmanship, featuring fiberglass tube, ⅛-wave optics, 50-mm. finder scope, retractable casters, and beautifully finished super-rigid ALUMINUM EQUATORIAL MOUNTING. De Luxe models also include 110-volt clock drive or the sensational new self-contained d.c. drive ASTRO-FIX, fully rotatable tube, and setting circles.

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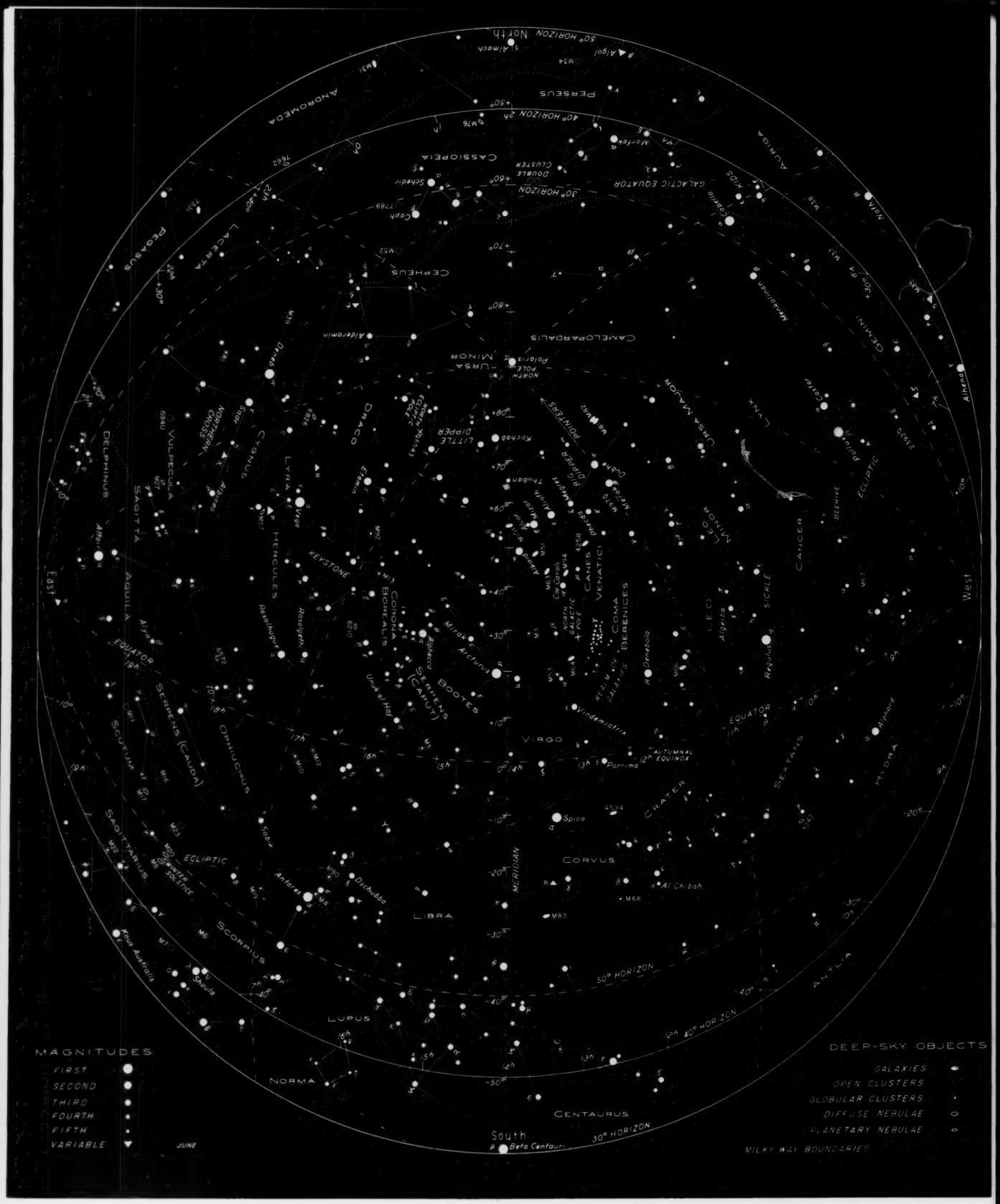
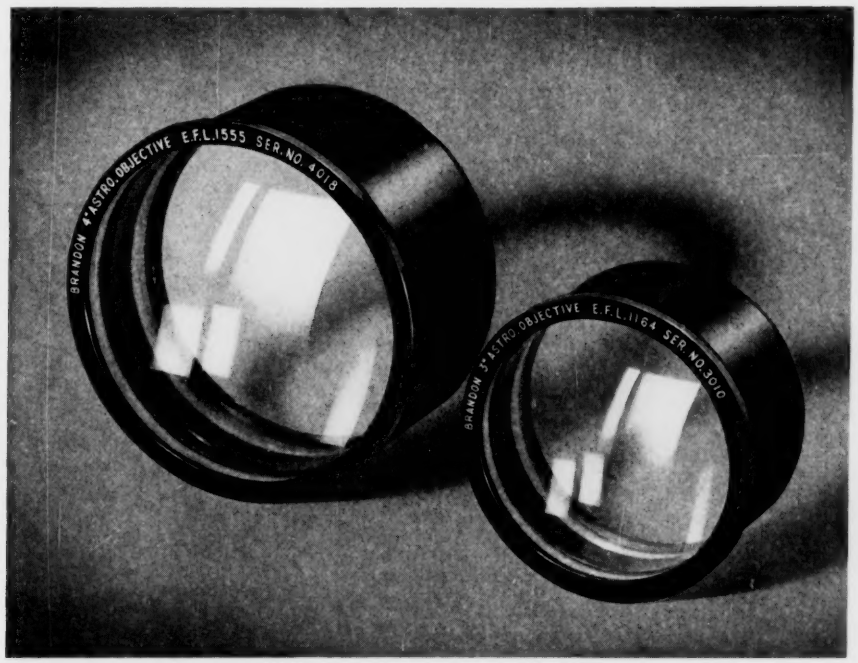


STARS FOR JUNE

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of June, respectively. For other dates, add or subtract ½ hour per week.

The time of this chart differs from your standard time by the distance your station is located east or west of the standard meridian. A list of such differences is given on page 125 of the January issue. In addition, an hour should be added if daylight saving time is shown on your clock.

Brandon Astronomical Objectives



Each 4-inch and 3-inch Brandon objective is shipped already mounted in a cell, ready to attach to your own tube of aluminum, brass, steel, or plastic.

NOW ANY AMATEUR CAN MAKE HIS OWN REFRACTOR!

As every exacting telescope user knows, the heart of a telescope is its objective lens or primary mirror. It is difficult to make the four surfaces of an achromatic two-element lens, and few amateurs tackle the task. But the mounting of a mirror and the maintenance of a reflecting telescope are often costly and time-consuming, while a refractor can be constructed easily and inexpensively with one of our astronomical objectives. The finished instrument requires little attention over the years and is always worth its original cost.

Therefore, if you want to get the most telescope for your time and money, buy one of our first-quality objectives and mount it yourself simply by attaching the cell to a tube of the proper diameter and length. The other end of the tube should carry a smaller sliding tube which in turn has an eyepiece holder. Focusing may be done by sliding one tube in the other, by rack and pinion, or by a spiral-focusing mechanism.

You have no diagonal support problem, no diagonal or prism to shake loose, no complicated aligning, no diffraction patterns of diagonal and support. Even the five-foot tube assembly of a 4-inch refractor is light and easy to mount as an altazimuth or equatorial instrument (see *Amateur Telescope Making—Book Two*, pages 192-211). It can be put on a tripod that is easily portable or on a permanent pier. Refractors are noted for the ease with which they can be set up and taken down; they pack easily into boxes for shipment and travel. The refractor lens provides a large field of excellent definition suitable for all kinds of eyepieces and for direct or projection photography. Either of our objectives, combined with any of our seven eyepieces, gives a wide range of powers:

Size of eyepiece:	4-mm.	6-mm.	8-mm.	12-mm.	16-mm.	24-mm.
3-inch f/15 lens:	290x	195x	145x	95x	75x	50x
4-inch f/15 lens:	390x	260x	195x	130x	95x	65x

When atmospheric conditions permit, you can take advantage of the well-known resolving power of the refractor. You have the perfect instrument for observing details on the planets, such as Mars when nearest to us this summer. Each Brandon lens is rigidly tested for its resolution of double stars before being sold. Brandon objectives enjoy an enviable reputation among professional and amateur astronomers for their fine performance. Check these features:

1. Superior optical design utilizing a larger air separation. Color corrected on C and F and hand corrected to reduce residuals to a minimum. Completely free of coma.

2. Glass-air surfaces magnesium-fluoride coated, increasing light transmission approximately 10 per cent.

3. Quality optical glass precision annealed and held to one ring test-plate match.

4. Cell made to precision tolerances and suitably coated to prevent stray light reflections. Each cell engraved with effective focal length and serial number.

These objectives are supplied with cells and rigidly tested on double stars for resolving power before being sold:

3″ Clear Aperture	**45.8″ Focal Length**	**$ 62.00**
4″ Clear Aperture	**61.2″ Focal Length**	**$138.00**

Your order, accompanied by check or money order, will be filled immediately and sent air-mail insured.
Send self-addressed 6¢ (air mail) stamped envelope for other dimensions. Satisfaction guaranteed, or your money will be refunded.

Brandon Instruments

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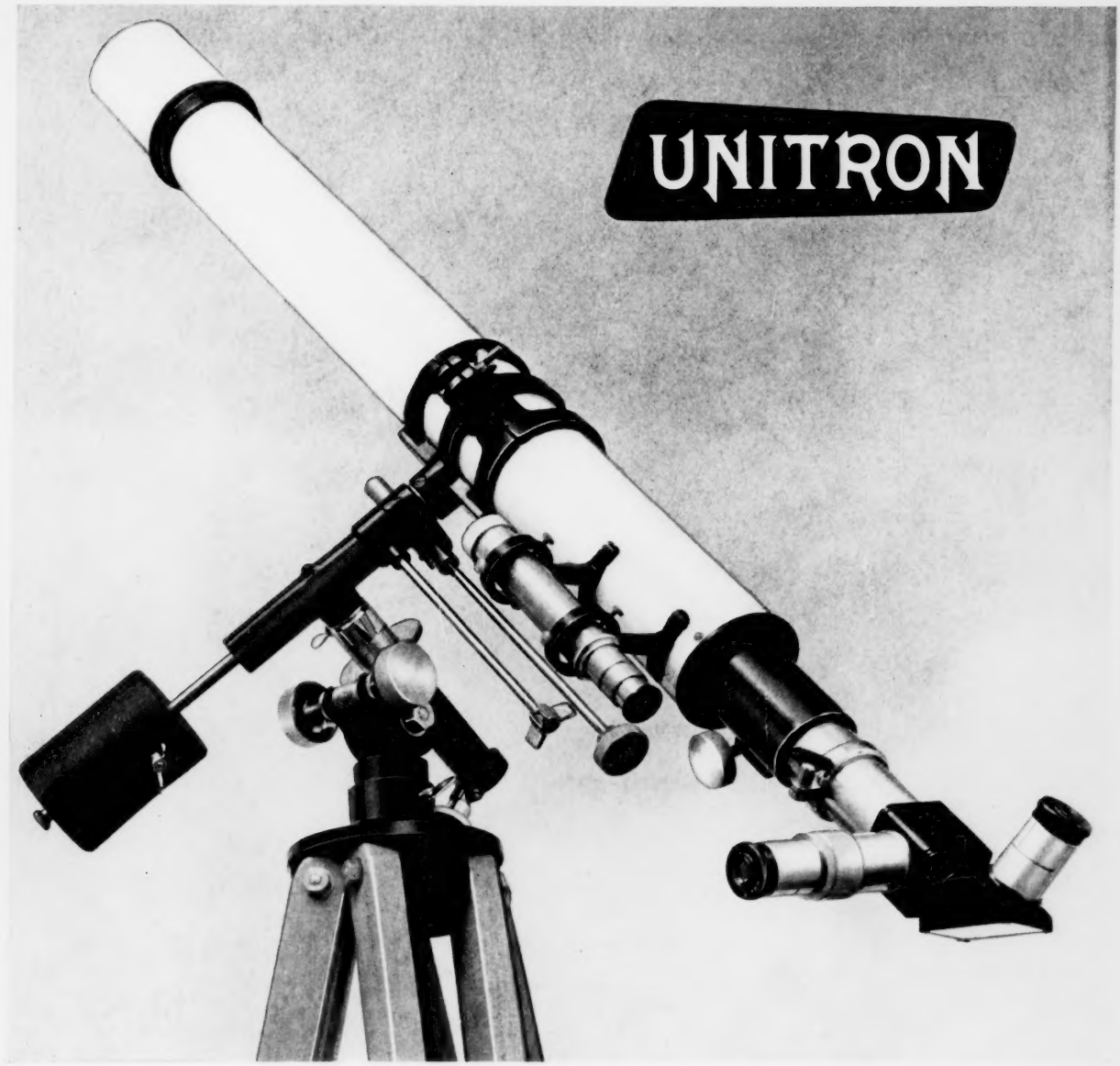

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The UNITRON 2.4" models are but two of the eleven famous UNITRONS that you have heard so much about. Don't miss out on the fine observing — treat yourself to a UNITRON.

See pages 378 and 379.

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